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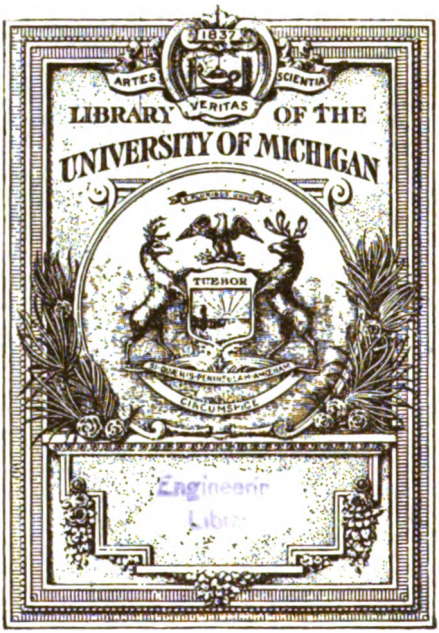

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THE RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

VOL. II JANUARY, 1921 NO. 1

Editor:
PROFESSOR G. W. O. HOWE, D.Sc., M.I.E.E.
Assistant Editor:
PHILIP R. COURSEY, B.Sc., A.M.I.E.E.

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Editor: Prof. G. W. O. HOWE, D.Sc., M.I.E.E. Asst. Editor: PHILIP R. COURSEY, B.Sc., A.M.I.E.E.

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THE
RADIO REVIEW

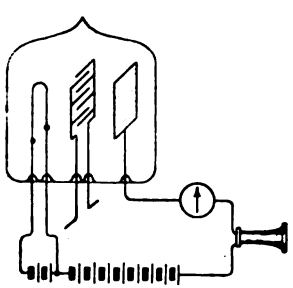
VOL. II JANUARY, 1921 NO. 1

Editorial.

The New Volume.—With this the first number of our second volume, we introduce several improvements with the object, firstly, of making the RADIO REVIEW of greater interest and usefulness to its present readers, and secondly, by broadening the scope of the articles published, to appeal to a wider circle of readers. We appeal to our readers to bring the RADIO REVIEW to the notice of any one interested in wireless telegraphy who is not already a subscriber. It is only by obtaining an increased circulation that we can hope to be able to make further improvement in the character of the RADIO REVIEW.

In connection with the paper by Mr. G. C. Southworth on "Electrical Measurements at Ultra-Radio Frequencies," which we publish in this issue, it is interesting to note that the determination of frequency by the measurement of the length of stationary waves on wires was tried for wavelengths up to 1,100 metres at the Reichsanstalt in 1908. The parallel wires passed through an open window and across the grounds. The experiments were described by Diesselhorst in the *Jahrbuch der drahtlosen Telegraphie*, 1, p. 262, 1908.

On page 38 of this issue we publish a short abstract of a paper read by Professor Fleming before the Wireless Society of London on "A Four-electrode Thermionic Detector." In this connection it is interesting to recall the four-electrode detector described by Majorana in 1912 (see *British Patent* 23024/1912; *Lincei Rendic*, p. 274, 1912; *Jahrbuch der drahtlosen Telegraphie*, p. 462, 1913). Although differing in construction from that described by Professor Fleming, it sufficiently resembles it in principle to make a comparison of the two interesting. We reproduce the figure from the Patent Specification. The grid is made in two parts between which the P.D. to be detected is applied.



Majorana says that the potentials of the two parts should be equally above and below that of the filament. The plate current is reduced whichever direction the P.D. is applied to the divided grid, which the inventor calls the "electron deviator"; hence an applied alternating P.D. causes a reduction

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of the plate current and gives a deflection on the galvanometer. Majorana points out that it can thus be used as a relay.

It is interesting to note that he points out that it is a potential operated device and that sensitiveness can therefore be increased by using an oscillatory circuit with large inductance and small capacity, so as to obtain a large P.D. between the deviating electrodes. He goes on to say that one can reduce the capacity until one has only that of the deviating electrodes, as described by Professor Fleming under the name of resonance spirals.

Wireless Service between England and Geneva.—In agreement with the Swiss Federal Government Marconi's Wireless Telegraph Company, Ltd., have installed a 6 kW continuous wave valve station at Geneva for the especial use of the numerous newspaper correspondents attending the first conference of the League of Nations. Besides being the first radio station to give priority to Press messages the Geneva station was remarkable for the speed with which it was erected. It was not until late October that the project was first discussed between the Swiss authorities and the Marconi Company, and on November 3rd not a single part of the gear, all of which, including a 200 foot steel tower, had to be transported from England, had arrived at Geneva. Yet on November 9th the preliminary trials were carried out. The station was completed and the service commenced on November 15th, the day the conference opened. On that date no less than 10,000 words were cleared within a few hours after the commencement of the sitting. In addition to the primary service to a specially-erected station at Witham, Essxx, communication was effected with Csepel (Hungary), Nauen (Germany), Centocelle (Italy), and Barcelona (Spain).

Notwithstanding the haste observed in the construction there was nothing makeshift about the Geneva station; on the contrary, it was an example of the last word in radio engineering.

The transmitting apparatus comprised one Marconi standard 6 kW continuous wave valve telegraph set of the coupled circuit type, fitted with six "power" and four "rectifying" valves. The power was taken from the Geneva Supply Company and supplied to a 30 B.H.P. 500 volt 2-phase motor from which a 23 kW 110 volt D.C. dynamo was driven by belt. An emergency power plant was provided consisting of one 18 kW 110 volt D.C. Austin oil-engine generator. Each power set was provided with a slate panel switchboard. One 6 kW motor alternator was installed, taking supply from the 110 volt D.C. circuit giving a single phase supply at 500 volts 300 cycles. The voltage was raised to 7,500 by a step-up transformer, at which pressure it was fed to the valve transmitter panel.

The signalling circuit comprised special high-speed keys operated by a Wheatstone transmitter, the tape for which was "punched" on a Gell keyboard type perforator. The aerial was of the umbrella cage type with six radial members, supported by a single lattice steel self-supporting tower 200 feet high, each radial member being carried out to a 50 foot pole at a distance of 300 feet from the central tower. The earth system consisted of the usual galvanised iron plates and earth wires buried in the ground.

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Five miles from the transmitting station was a separate receiving station erected so as to permit of duplex working. This station was provided with a special aerial constructed on the latest directional principles, and was connected to the transmitting station by landline. From the central receiving office in Geneva the messages were passed to the transmitting station over a landline, this service being augmented by a squad of motor-cyclist messengers.

The receiving station in England was located at Witham, near Chelmsford. It was equipped with the latest type of directional aerial and in addition to up-to-date valve receivers was provided with dictaphone apparatus for the reception of high-speed messages.

For transmitting the necessary acknowledgments, service messages, etc., a 15 kW valve transmitter at the Marconi Company's works, Chelmsford, was operated direct from the receiving station at Witham by landline connection. Witham was also in direct landline communication with the Marconi Company's London offices to which the messages were finally transmitted by high-speed automatic apparatus.

Many thousands of words were daily handled by this service, which, besides relieving the Continental telephone and telegraph lines of an enormous weight of traffic, thus enabling the delegates of the League of Nations a freer use of these means of communication, was an excellent demonstration of the value of radiotelegraphy in the quick dissemination of news.

In our next issue we hope to publish an article giving a more detailed description of the installations employed in this service.

The Creed Printer as a Wireless Recorder.—At the inaugural address of the current session of the Royal Society of Arts delivered by Mr. A. A. Campbell Swinton on Wednesday, November 17th, 1920, a demonstration was given of one of the latest developments of wireless recording instruments. The lecturer prefaced the demonstration with a few introductory remarks outlining the methods of radio communication and then briefly described the Creed perforating and printing mechanism which were used for the demonstration. A special message was sent by arrangement from the Eiffel Tower, Paris, both for this meeting and for the meeting of the Wireless Society of London which was held in the same hall on the following day. A short account of the latter meeting will be found elsewhere in this issue together with a reproduction of part of the printed strip received on that occasion.* Although a few mistakes are noticeable in the final message as printed by the Creed machine it will be readily seen that these are of a minor character due mostly to the omission or addition of a dot signal. Some of these disturbances were possibly due to atmospheric effects.

The Creed instruments that were used were of the ordinary type customarily employed for landline telegraphic work and the novelty of the demonstration lay in their successful adaptation to wireless telegraphic reception. We hope in a future issue to deal with this subject more fully and to publish a detailed description of the apparatus that may be used for this purpose.

* See pp. 37–38.

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Commercial Progress in Aircraft Wireless.

By R. H. BARFIELD, B.Sc.

It is evident that progress in aeronautics must have an all-important bearing upon the development of aircraft wireless and it is also evident that wireless must form an important contributory factor in the future development of aeronautics. Progress in aeronautics has been phenomenally rapid in the last few years, and, notwithstanding the fact that since the incentive of war has been removed an appreciable slackening down has taken place, it is reasonable to anticipate that a steady rate of advance will be maintained and later, when accumulated experience and improved facilities have resulted in a greater measure of reliability, there will be an accelerated rate of development accompanied by an extended use of wireless.

In aeronautics much depends upon the possibility of reliable communication with the ground and, to a lesser extent, between aircraft in flight; and wireless provides the only means by which this can be achieved. The advantages accruing from such communication may be classified under two heads. Firstly, those which are connected with navigation and control and therefore make for increased safety and reliability and secondly those which add to the convenience and perhaps to the comfort of passengers and so tend to popularise the service. Owing to the relatively high speed of aircraft and the consequent brief duration of the journeys undertaken the second consideration is comparatively unimportant at the moment but it is probable that, as the length of aerial routes increase and their use by the public becomes more general, it will merit more serious attention. The principal technical difficulties have been overcome and it is now possible to establish communication, partly by wire and partly by wireless, between an office in London, for example, and a machine on the London-Paris route. The linking of the air route wireless stations to the Post Office telephone system is all that is necessary to bring this service within the reach of the public.

In its use for the purposes of navigation and control, wireless performs somewhat analogous functions in the air and on the sea but the conditions differ to such an extent that it has markedly greater possibilities in the former than in the latter sphere. The aerodrome is more to the aeroplane than the harbour to the ship for, unlike the ship, the aeroplane cannot anchor or stand off indefinitely when conditions are unfavourable for landing, hence it is important that the pilot shall be in touch with his objective in order that he may be acquainted with conditions there and diverted to an alternative aerodrome if necessary.

Navigation at sea is in the hands of a qualified officer who is in a position to devote time and care to the performance of this duty. In the absence of astronomical observations he can carry on and proceed for days by dead reckoning, *i.e.*, by compass and log, and in shallow waters he has a check in the use of the lead. Definite information is at hand regarding ocean currents and the tides and he can always heave to or anchor if desirable. Navigation by astronomical observation is hardly practicable in the case of

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commercial aeroplane traffic and indeed it would be of little use in the case of journeys of the length at present contemplated. Aircraft navigation by dead reckoning alone is liable to enormous errors due to the very large drift allowances necessary, the uncertainty regarding the strength or even direction of wind at different altitudes and the very high speed of travel. The wireless direction finder provides a means of checking position at intervals, however, so that navigation can be carried out with the aid of wireless under conditions when it would be impossible otherwise owing to the absence of landmarks or their obscuration by cloud, fog or darkness.

Important as is the *rôle* of wireless at sea, it will be agreed that an even more important *rôle* is assigned to it in the air where, under frequently prevailing conditions, it forms the sole means of communication between aircraft and the ground and the sole agency by which navigation becomes possible. The design and development of suitable wireless equipment for communication between aircraft and the ground and for aircraft navigation becomes, therefore, an important item in the programme of those engaged in the production of wireless apparatus.

It will be of interest to consider what special problems arise in connection with this particular branch of wireless engineering, how they have been dealt with and on what lines the various difficulties are being overcome. In the case of the apparatus for installation in aircraft as distinct from the corresponding ground equipment there are special difficulties associated with the necessity for drastic economy in weight and space. This consideration operates in more than one way; it limits the power of the transmitter and the size of the aerial, both of which affect the range, and it renders impracticable, or at any rate undesirable, the carrying of an expert whose attention may be solely devoted to the care of the wireless gear. The installation must therefore be of a simple nature capable of operation by a person unskilled in wireless matters and who has other duties to perform. Now complexity of apparatus cannot be dispensed with beyond a certain point without detriment to its performance hence the problem resolves itself into the provision of apparatus which may be described as normal or nearly so from the point of view of general wireless design though especially light and compact and at the same time simple to operate.

The introduction of the three-electrode valve has been the controlling factor in the developments which have taken place. It has made reception in aircraft a practical proposition and has brought into being telephonic transmission whereby the necessity for a trained "Morse" operator is dispensed with and speed of transmission, a most important factor, has been increased tenfold.

Reception in aircraft is carried out under what are probably the worst possible conditions and the difficulties were at first sufficiently great to put a stop to any serious attempt at reception, with the result that wireless in aircraft originally took the form of one-way working with the transmitter in the aeroplane. The overwhelming noise produced by the unsilenced engine made impossible the reception of any but the very strongest signals, the presence of intense vibration rendered the use of the ordinary contact

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detectors impossible and when highly sensitive valve amplifiers were introduced induction from the magneto circuits gave serious trouble.

The receiver must be sensitive and must provide considerable amplification in order that loud signals may be obtained and the whole installation must be of a robust nature capable of withstanding the most severe conditions of weather, vibration, temperature changes, etc., and at the same time must be so simple in its working as to be capable of operation by any one without special knowledge of the subject.

A brief description of a commercial installation of recent design will serve to indicate the stage of development at present reached. The apparatus referred to is that manufactured by the Marconi Company, and installed in aircraft of the leading aerial transport lines. It consists of a combined transmitter and receiver primarily intended for wireless telephony, but capable also of being used for either " tonic train " or continuous wave telegraphy. A single three-electrode valve generates the high frequency oscillations and an air-screw generator provides power for the whole of the set. The employment of a system of remote control enables the apparatus to be operated and adjusted by the pilot, and as the small unit which contains the controlling handles occupies very little space it can be mounted in the most convenient position. When once the preliminary adjustments have been made operation becomes extremely simple. The pilot on wishing to speak to any station with which he is in range has only to set the change-over switch on his remote control to the " send " position and call up the station by name. When he has finished his conversation he sets his switch

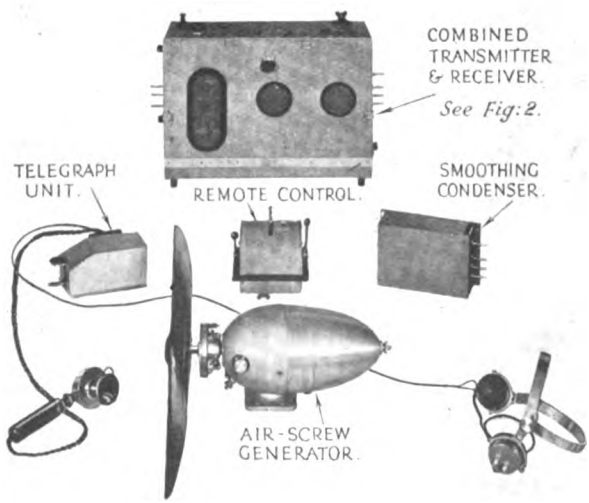

FIG. 1.—Aircraft Transmitter and Receiver (Combined Type). Assemblage of Units.

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to "receive" and awaits the reply. Normally the switch will be in the "receive" position and as he will be wearing the telephone head-gear at all times the pilot will always be ready to hear any one who may be calling him.

Fig. 1 shows an assemblage of the units which go to form the complete installation. The unit method of construction makes it possible in mounting the set to take advantage of odd spaces on the aeroplane which would otherwise be useless. It also enables a damaged unit to be replaced or repaired independently.

The apparatus comprises :—

(1) The transmitter and receiver mounted either in one box or in two separate boxes, which, in either case, are protected from vibration by suspension on rubber shock absorbers.
(2) The remote control unit (see Fig. 6).
(3) The generator (with air screw).
(4) Smoothing condenser.
(5) Microphone and head receiver.
(6) The telegraph unit.
(7) Aerial and winch and earth connection.
(8) Six-volt battery.

The complete set, installed in an Airco D.H.6 machine which is now employed on Continental transport work, is illustrated in Figs. 3, 4, 5, and a simplified diagram of connections of the transmitter and receiver is shown in Fig. 7.

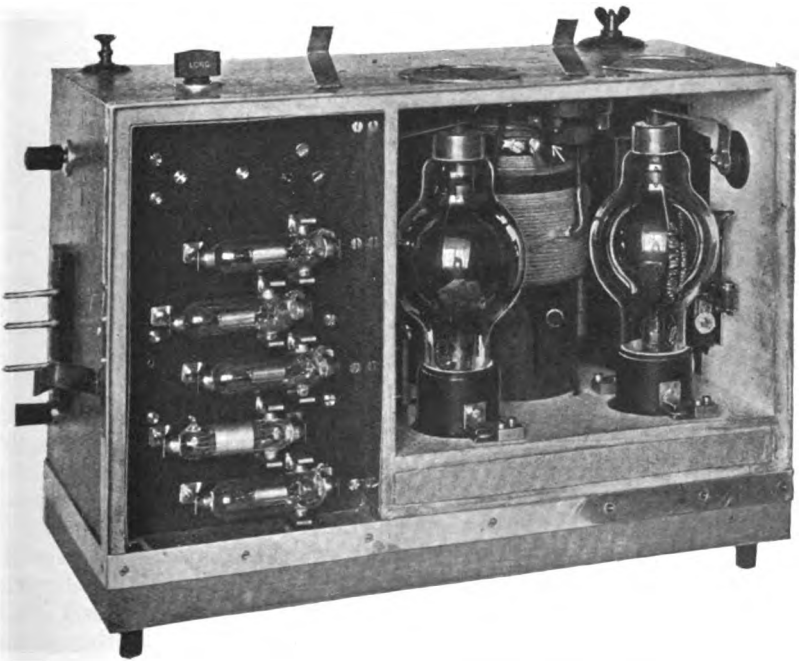

FIG. 2.—Interior of Transmitter and Receiver Box.

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The transmitter consists of an aerial circuit coupled directly to the plate circuit of the oscillating valve. The amplitude of the oscillations in the latter are variable by means of a control valve, both valves being supplied

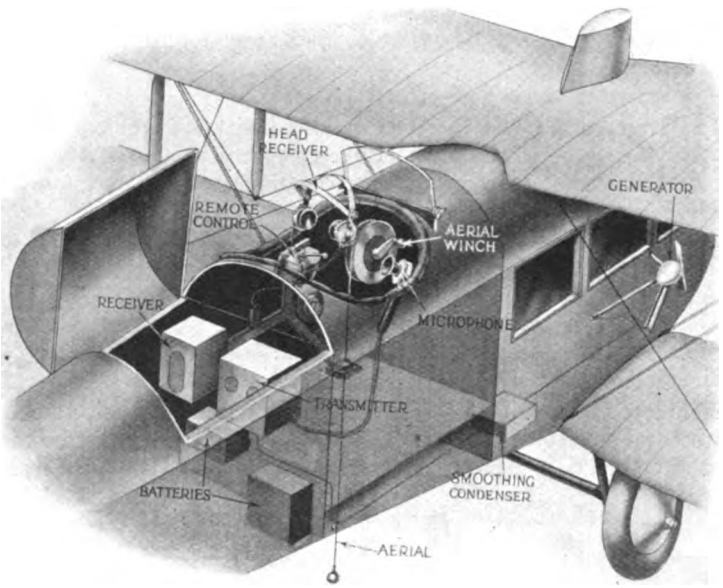

Fig. 3.—The Complete Set mounted on an Airco Machine (Type D.H.6).

with high-tension direct current energy from the air-screw generator. Variations in current produced by speech in the microphone are impressed on the grid circuit of the control valve through a step-up transformer, and a "speech" choke is inserted in the high tension supply circuit common to the two valves. Two working wavelengths are provided, either one being put into use by means of a wave-changing switch. Fine adjustment of the aerial circuit is obtained by means of the variometer, which when once set on the test flight needs no further attention.

In the receiver a simple aerial circuit is variably coupled to a five-valve amplifier, of which the first three valves are for high-frequency amplification, the fourth for rectification and the last for note magnification.

A coarse wavelength adjustment is provided by means of a three-way switch connected to a subsidiary inductance in the aerial circuit. This switch, which is mounted on top of the box, enables a wavelength of from 450 to 1,000 metres to be obtained. Fine tuning is carried out by means of a small condenser incorporated in the remote control unit and shunted across the aerial and earth. The pilot is thus able to make the necessary adjustments for small variations which may be found in the wavelengths

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of stations transmitting to him though nominally all tuned to the same standard wavelength.

The aerial circuit is inductively coupled to the first high-frequency valve through a coil, which, when the coupling is loose, has a natural wavelength equal to that of the standard wave to be worked to. On tightening the coupling, however, the increased mutual inductance brings in two possible resonance points, one higher and one lower than that obtained with loose coupling. Thus, by varying the coupling the secondary circuit is tuned, and by varying the coarse wavelength switch in combination with the remote control condenser, the aerial circuit is tuned. In this manner the advantages of loose coupling are obtainable on the standard wave, and tuning to a large range of other waves is obtained by a simple adjustment.

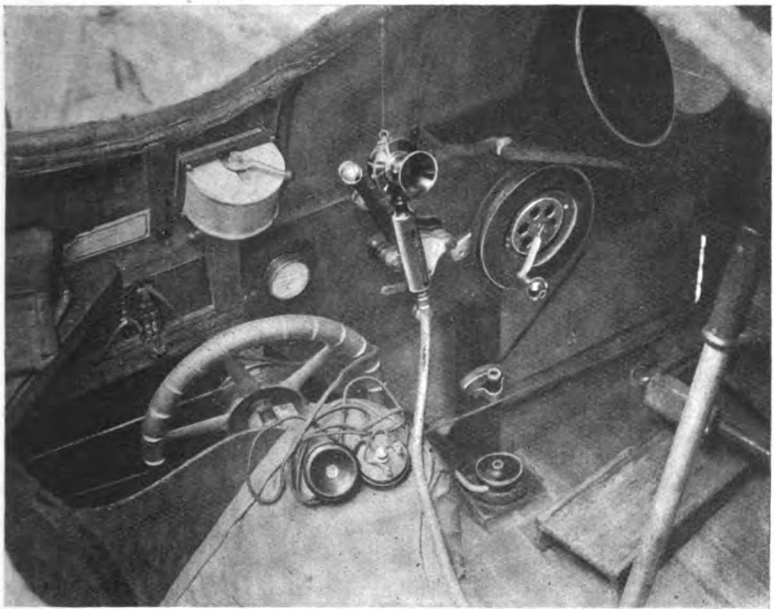

FIG. 4.—Pilot Cockpit, showing Control Gear and Aerial Winch.

Screening is carried out very thoroughly. In order to prevent interference by induction from the engine ignition circuits, screening of the magneto leads and, if necessary, the magneto itself, is resorted to and is carried out by means of wire gauze which is earthed, also the whole of the high-frequency circuits are screened in one metal box, and further, the coupling and aerial coils are screened themselves from the high-frequency transformers. This prevents undesirable oscillation, and makes for stability. Reaction is arranged for so that the set can be made to oscillate and work as an auto-heterodyne circuit for the reception of continuous waves, or

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brought into a condition of increased sensitivity for the reception of weak signals. These adjustments are made by a twist handle mounted below the coupling handle. If used as a pilot-operated set, this handle is fixed so that a maximum of sensitivity is obtained consistent with stability.

The high-frequency transformers are damped very heavily so that the amplifier is sensitive over a wide range of wavelengths and the reaction adjustment is fully controllable and practically unaffected by wavelength changes or filament brightness.

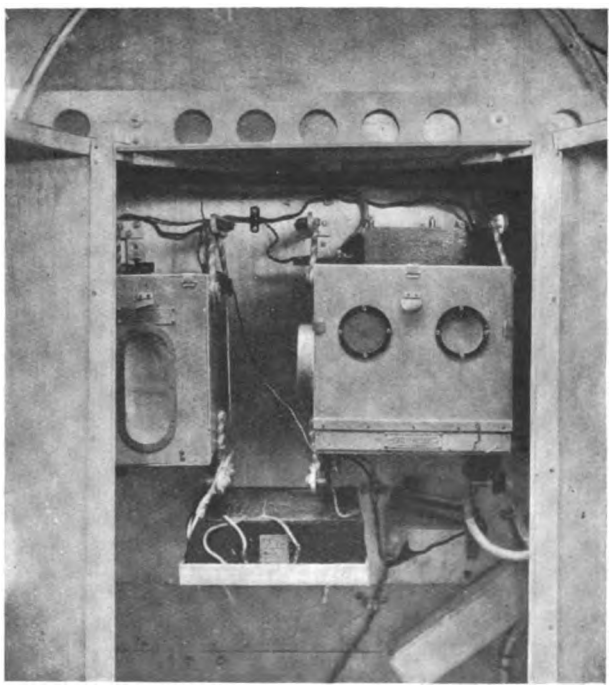

FIG. 5.—Rear Cockpit, showing disposal of Transmitter and Receiver Boxes with Batteries.

The strength of signals is varied by means of the remote control variable resistance which is in series with the filaments of the valves.

The telegraph unit * contains a key, a buzzer and a switch. The switch controls the method of transmission. In its first position the key is connected in the grid circuit of the oscillatory valve for continuous wave transmission. In the second position, for "tonic train" telegraphy, the grid circuit is closed so that the set is continuously oscillating and the key now controls the buzzer which is connected to the step-up transformer in the

* This unit is not included in the equipment shown in Fig. 3.

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grid circuit of the control valve. In the third position connections are the same as in position two, except that the microphone is substituted for the buzzer and key.

The aerial is of the trailing type and consists of a flexible phosphor-bronze wire 200 feet long, carrying a 2½ lb. spherical weight at its lower end. When

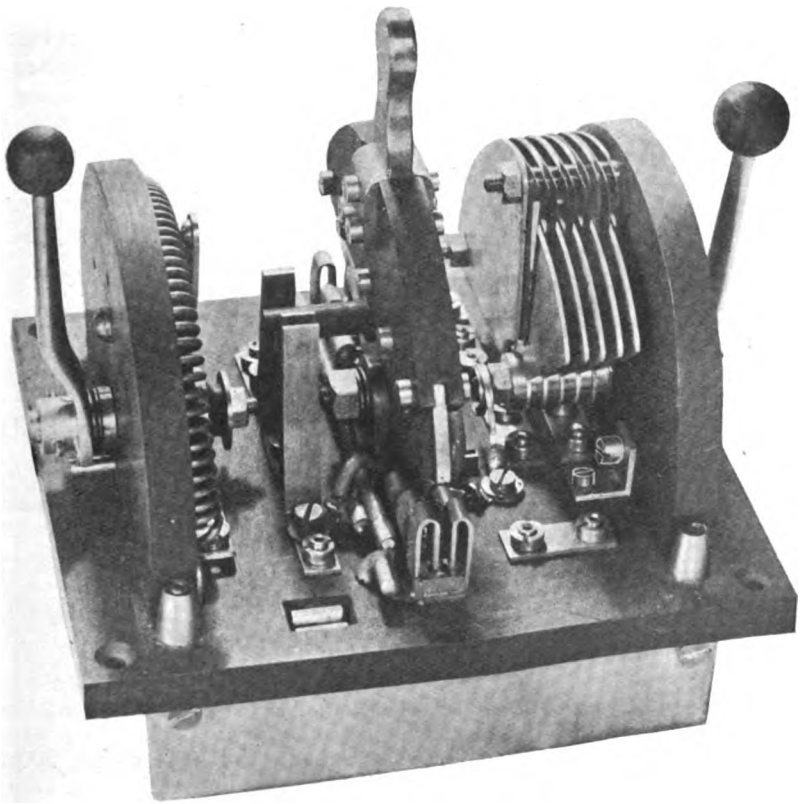

FIG. 6.—The Remote Control Unit.

not in use it is coiled up on a specially designed winch. When the machine is in flight, the pilot releases the winch and the aerial trails out beneath the machine. Earth connection is made to all metal parts of the machine by means of a " bonding " strip which runs along the fuselage.

The complete installation weighs only some 60 lbs. and the ranges under normal conditions are approximately 200 miles for C.W. telegraphy, 130 for " tonic train " telegraphy and 100 miles for telephony.

Ground stations for working with aircraft have been standardised and on an aerial route these stations are erected at intervals designed to ensure

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continuous communication with machines using the routes. In these stations, in addition to apparatus for telegraphy and telephony, a complete direction finding installation is provided and, by means of this, bearing can be obtained of any machine from which signals are received. Where auxiliary direction finding stations are available, simultaneous observations are made, a " fix " obtained and the information communicated to the pilot through the main station.

The whole station is under the control of a single operator by means of a small switchboard or control unit. The transmitter and power plant are usually housed at some distance from the room in which the receiving and

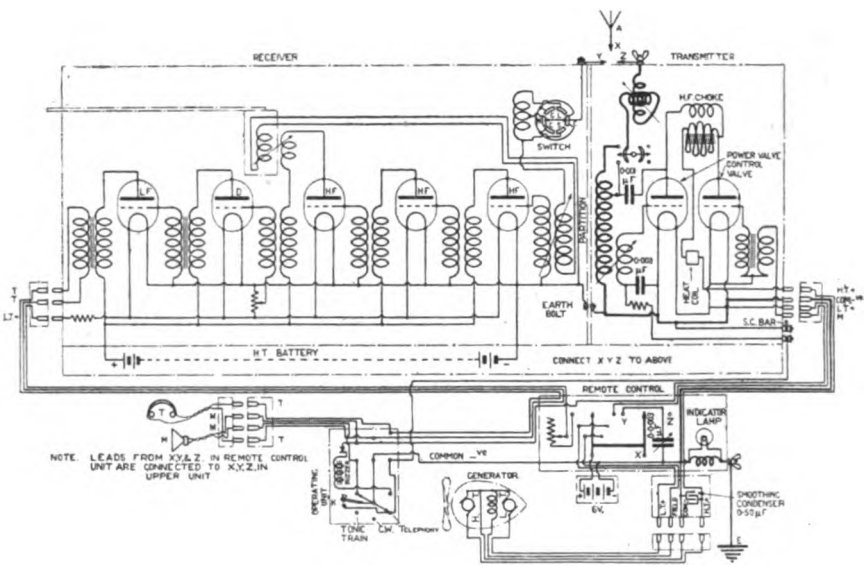

FIG. 7. Diagram of Connections of Aircraft Transmitter and Receiver.

control instruments are contained. A separate aerial 70 feet high, 200 feet long is employed for transmitting, and direction finding aerials are used for normal reception purposes.

The transmitting installation comprises the power unit, consisting of a motor-generator and switch-board, the high-frequency generating apparatus with speech control apparatus and the tuning circuits with wave-changing gear ; the whole being operated by a system of relays which are manipulated from the control room.

A wavelength range of from 300 to 3,000 metres in suitably graded steps is obtainable, the change from one wave to another being effected by means of a simple switching system.

The extremely long wavelength range over which the installation is capable of transmitting necessitates the employment of two systems of speech control. The " damping " method of control is employed when working

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on wavelengths of the order of 900 metres and upward, whilst for shorter wavelengths the " choke " or " anode " system of control is employed.

In both cases two control valves are connected in cascade—an arrangement which ensures the powerful control necessary in a transmitter designed to operate with weak speech currents from a land line circuit.

The simplified diagram (Fig. 8) shows the connections of the valve apparatus for generating high-frequency oscillations and indicates how both methods of control are carried out.

Landline connection is obtained by operating a switch mounted on the control board which enables the operator to put his wireless microphone and receivers on to the landline and call up the terminal station or exchange

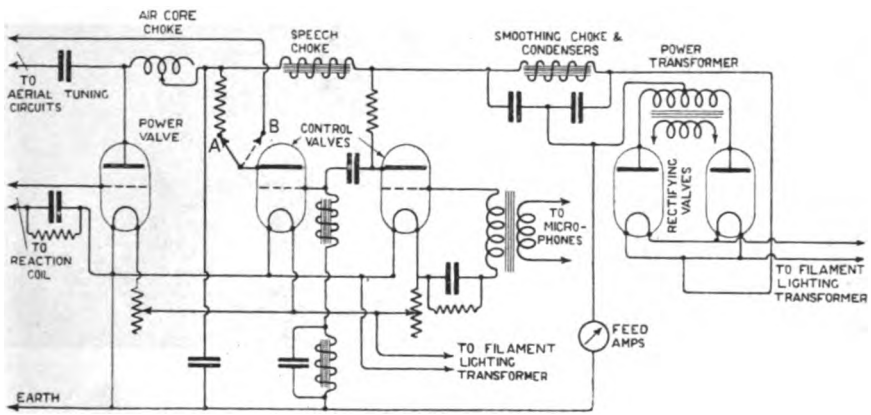

FIG. 8.—Simplified Diagram of Ground Station Valve Transmitter (Telephony Arrangement).

in the usual way. A second switch enables him to connect the wireless apparatus through to the line, allowing him to listen in during the conversation for the purpose of " changing over " when necessary.

Repeaters are employed as connecting links between the landline and wireless so that the necessity for metallic connection is obviated.

The remote control switchboard (illustrated in Fig. 9) has mounted on it five switches which put the operator in complete control of the station.

These switches perform the following operations :—

No. 1.—The transmit-receive switch enables the change over from sending to receiving conditions or *vice versa*, to be effected. The switch, when placed to transmit, controls a relay switch which energises the wireless transmitting circuits. At " receive " the transmitting circuits are made inoperative by the same means and the receiver is switched into operation.

No. 2.—The motor switch controls a relay which starts or stops the transmitting power plant.

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No. 3.—The transmission switch controls the method of transmission. At "Telephony," relays are actuated which energise the control valves and the microphone is switched into operation. At "Tonic Train" the switch inserts a buzzer in series with a key and battery in place of the microphone. At "Telegraphy" the control valves are cut off and the key is connected so as to control the keying relay in the oscillating valve circuits.

No. 4.—The line hold switch; when this switch is changed over from "clear" to "hold" the exchange line is automatically held so that the operator can call up the distant wireless station which the subscriber on the exchange line is asking for.

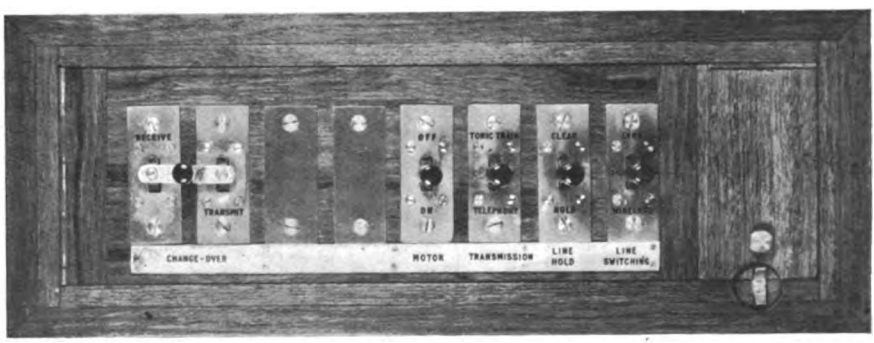

FIG. 9.—The Remote Control Switchboard (Ground Station).

No. 5.—The line switch has three positions, in the first—"Wireless"—the wireless instruments are entirely independent of the exchange lines. The second position is the "Through" position and the distant wireless station is then put into communication with the subscriber on the landline and the operator "listens in."

In the third position—"Line"—the operator is connected so as to be able to converse with the line subscriber. The switch is only put into this position when the change-over switch is at "Receive."

The receiving apparatus is similar to the well-known standard Marconi Direction Finder in which is incorporated a six-valve amplifying detector. For ordinary "all round" reception the aerials are bunched together and put to earth through a coil which is tightly coupled to the tuning circuit but for directional reception they are connected to the fixed coils of the radiogoniometer. The present standard pattern incorporates an arrangement of circuits which enables the "sense" to be determined as well as the direction and this very much increases the value of the readings taken by an individual station.

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The Heterodyne Method of Wireless Reception, its Advantages, and its Future.*

By MARIUS LATOUR.

It is generally known that at the present time wireless antennæ are supplied with alternating current produced by arcs, or by alternators similar to those used for power purposes but of higher frequency. Although this frequency has recently been lowered to about 12,500 cycles (in the Bordeaux Station), we cannot yet receive this current in the ordinary telephones because their sensitiveness is very small for frequencies above 2,000.

We must therefore look for another method of detecting these high frequency currents with the telephone, and of transforming the inaudible signals into audible ones.

M. Maurice Leblanc was the first to devise a means of making high frequency currents directly audible. While Elisha Grey in America was the inventor of multiple harmonic telegraphy based on the simultaneous utilisation of currents of as many different frequencies as there are messages to be sent, Leblanc was the inventor of a similar system of multiple telephony using currents of higher than the speech frequency. These high frequency currents were modulated by the microphone itself. In other countries the invention of high frequency multiple telephony is generally attributed to General G. O. Squier, who however did not put forward his suggestions until a long time afterwards.

In *La Lumière Electrique* of April 17th, 1886, in a paper on "Multiplex Telephony," M. Leblanc showed how it is possible to vary the amplitude of an inaudible high frequency current, so as to make it audible. He endeavoured to devise a special telephone to respond to the effective variations in the intensity of a high frequency current without using either detector or rectifier. This instrument was based on the principle of the electrodynamometer. It consisted merely of two circular parallel coils connected in series, one being fixed and the other attached to an ebonite diaphragm (see Fig. 1). It is obvious that the effective variations in intensity of the high frequency current will cause variations in the attraction between the two coils, which will produce vibrations of the ebonite diaphragm.

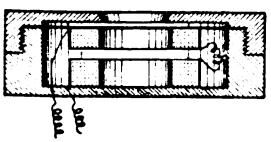

FIG. 1.

In a note sent to the General Electric Company at Schenectady in September, 1904, we proposed to receive radio signals by producing "beats" between two simultaneous radiations of different frequencies. Two alternators coupled to two distinct antennæ and working at frequencies of

* Received November 12th, 1920.

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29,000 and 30,000 respectively would emit a note of 1,000 ~. This note may be received directly by a telephone of the electrodynamometer type such as that suggested by Leblanc.

In practice however it is not necessary for the two transmissions to be effected at the same place. One of these can be set up at the receiving station itself. This in fact constitutes the principal feature of Fessenden's invention. The distant transmission to be received being of frequency 30,000, a feeble local oscillation of 29,000 cycles is set up in order to establish the beat note of 1,000 cycles. Fessenden has termed this little generator for use at the receiving station to produce the local oscillations a "heterodyne."

Using this local oscillation generator it is possible to design a special telephone which, like that of Leblanc, permits the reception of a high frequency current without detection or rectification. Fessenden described the following arrangement. An electromagnet (see Fig. 2) able to attract a diaphragm P carries two windings e_1 e_2 through one of which passes the current from the local source, while the antenna current passes through the

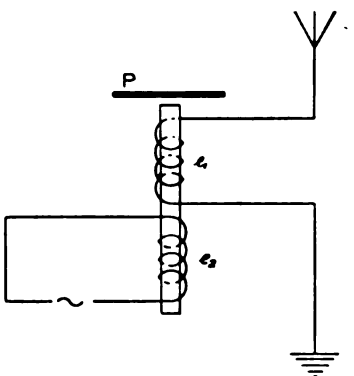

FIG. 2.

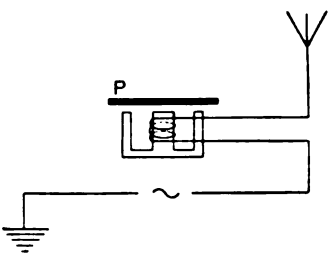

FIG. 3.

other. These two currents have frequencies $\frac{\omega_1}{2\pi}$ and $\frac{\omega_2}{2\pi}$ respectively, and they set up a resultant flux in which the effective intensity has a periodicity corresponding to $(\omega_2 - \omega_1)$.

Working on this principle we have successfully made telephones on the lines of Fig. 3,* with which we have received the large radio stations without any other detector. By using in the magnetic circuit of the telephone very fine wire such as is now obtainable commercially, the windings e_1 e_2 may be combined into one, a simplification of great practical importance. We have also described the use of a local oscillation of greater strength than the received signal.

* See British Patents Nos. 100281 and 111475.

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The telephone circuit is traversed simultaneously by the local current $I \sin \omega_1 t$ and by the received current $i \sin \omega_2 t$. The resultant flux is proportional to $I \sin \omega_1 t + i \sin \omega_2 t$; the attraction of the diaphragm is proportional to the square of the flux,

i.e., to $I^2 \sin^2 \omega_1 t + i^2 \sin^2 \omega_2 t + 2Ii \sin \omega_1 t \sin \omega_2 t$ or

$$\frac{I^2}{2} - \frac{I^2}{2} \cos 2\omega_1 t + \frac{i^2}{2} - \frac{i^2}{2} \cos 2\omega_2 t + Ii \cos(\omega_1 + \omega_2)t + Ii \cos(\omega_1 - \omega_2)t.$$

The first five terms of this expression give rise either to continuous attraction of the diaphragm or to vibrations of a very high frequency of twice the frequency of the local received current, a frequency which the telephone diaphragm would not be able to follow. The last term represents, on the other hand, a periodic attraction which may be of musical frequency, if the difference $\omega_1 - \omega_2$ be sufficiently small.

It should be noticed that this attraction is not only proportional to the received current, but also to the local current. It is therefore possible to increase the sensitiveness of reception by increasing the local current, but at the same time it must be remembered that the permanent attraction represented by the first two terms in I^2 tends to prevent the vibration of the diaphragm.

The analogous case of the ordinary telephone which we have analysed in a previous paper in the *Lumière Electrique* of June 28th, 1916, obviously applies here, as the local high frequency source may be regarded as replacing the permanent magnet or the source of excitation of continuous current in the case of the electromagnetic telephone. A high frequency telephone without a predominating local high frequency source, with $I = i$ for instance, would have a very small sensitiveness, like Leblanc's telephone, and could not be used in practice.

The amplitude of the vibration of the diaphragm is proportional to the current i, and distant or weak stations as well as strong stations will be received with strength proportional to the received antenna currents. This matter will be referred to later.

However, it is curious to notice that even if the property of rectification had not been already discovered (such as in the case of coherers, crystals, valves, etc.) the reception of wireless telegraphy signals would still have been possible by purely engineering methods, and by the means employed in electrodynamic machines. As the wavelength is increased, that is to say, as the frequency is diminished, this method of direct reception becomes more and more practicable. If we add that the currents for both transmission and reception can be produced by high frequency alternators, we see that the utilisation of the magnetic properties of iron alone is sufficient for all wireless communication.

It is noticeable that the sensitiveness of the telephone described previously is very small for atmospherics, as these cannot give true beats with the local current. We have therefore a telephone without a permanent magnet which is sensitive only to beats produced by a local H.F. current, and thus a strong current of 1,000 frequency in the aerial circuit of Fig. 3 would give

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but a comparatively feeble sound. Apart from special telephones for the reception of H.F. currents, an attempt has been made to use a local source, or heterodyne, for reception by beats, in cases where the high frequency current is detected or rectified.

This arrangement is the usual one at the present time. It is indicated in Fig. 4, where a secondary circuit is shown. D is the rectifying detector, and T the telephones which are of the ordinary type. In comparison with direct reception without heterodyne this method has an extraordinary sensitiveness for weak signals. In an article published in the *Electrical World* (New York), April 24th, 1915, the now well-known simple explanation of this fact was given for the first time.

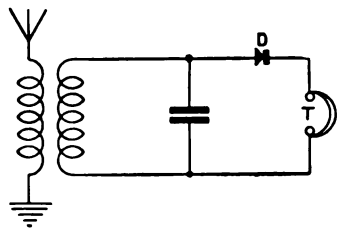

FIG. 4.

At the discussion on "The Probable Progress in the Reception of weak long-distance Radio Signals," held in March, 1914, by the Société Française des Électriciens, M. Henri Abraham said :—

"We know, but it is a fact little comprehended, that crystal detectors, valves and many other forms are really rectifiers of alternating current only when used for strong currents. But when they are actuated by weak long-distance wireless waves giving an E.M.F. often less than one volt, experience shows that *the rectified current from the detector is directly proportional to the square of the applied E.M.F. The output of the detector is proportional to the power of the oscillations to which it is subjected.*

"Besides the progress which is sure to be made in the transmitter, by increasing the power of the stations, the increase in the wavelength, and the improvement in the methods of aerial excitation, there remains much to be accomplished by improvements in the methods of reception. *It is essential that weak signals should produce as much response as the stronger ones.* Thus full effectiveness will be given to musical note transmission, and to sustained waves."

The heterodyne method of reception fulfils these conditions.

This progress depends not only on the beat method of reception, but also on the utilisation of a local generator. By this means, in fact, we can always obtain a current which may be as strong as desirable for good rectification, however weak the signals themselves may be. Consider the resultant of a local current $I \sin \omega_1 t$ and the received current $i \sin \omega_2 t$, referring everything to the frequency of the former we have :—

$$I \sin \omega_1 t + i \sin \omega_2 t = I \sin \omega_1 t + i \sin \{\omega_1 + (\omega_2 - \omega_1)t\}$$
$$= \sin \omega_1 t\,[I + i \cos (\omega_2 - \omega_1)t] + \cos \omega_1 t\,[i \sin (\omega_2 - \omega_1)t].$$

If $(\omega_2 - \omega_1)$ is small compared with ω_1, consider an interval of time very small compared with $\frac{2\pi}{\omega_2 - \omega_1}$ but several times as great as $\frac{2\pi}{\omega_1}$, then at a time

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t, the maximum amplitude of the resultant current of frequency $\frac{\omega_1}{2\pi}$ will be the square root of the sum of the squares of the factors $\sin \omega_1 t$ and $\cos \omega_1 t$, *i.e.*, $\sqrt{I^2 + i^2 + 2Ii \cos(\omega_2 - \omega_1)t}$. The detector will give a rectified current proportional to the square of this expression, viz.,

$$I^2 + i^2 + 2Ii \cos(\omega_2 - \omega_1)t.$$

The first terms of this expression being constant, it will be the second, of the audible frequency corresponding to $(\omega_2 - \omega_1)$, which will be heard in the telephones. The sensitiveness of reception will be proportional to the local current I, and the signal strength proportional to the received current i. Evidently it is not possible to indefinitely increase the sensitiveness of the receiver by increasing the local current I. As a matter of fact, this sensitiveness will reach a maximum as we have previously indicated * for that value of the local current I corresponding to the critical value beyond which the rectified output of the detector is directly proportional to the current passing through it.

Without the heterodyne, a very small received current becomes, after detection, a quantity of the second order of smallness, whilst in heterodyne reception it remains of the same order. Thus we see at once the decided advantage of this method for weak signals. Heterodyne reception is much more suitable for undamped than for damped waves. We have elsewhere suggested † the use of the heterodyne in reception in wireless telephony in order to increase the sensitiveness. In view of the above it seems that the future of reception by heterodyne and detector is assured. However we must note the following points :—

By the use of the modern high frequency amplifier it is possible before detection to so magnify up a weak signal that the advantages of the heterodyne referred to above are no longer effective.

Recently M. Abraham introduced into France the reception of American stations without heterodynes. A sustained high frequency transmission simply gives place after detection to a continuous current the value of which can be recorded.

To fully appreciate the superiority or inferiority of this method of reception compared with that using the heterodyne, we must first take the point of view of the protection which they afford against atmospherics—always an important factor. Now as far as experiments have been made it still remains to be seen if, in reception by recording the received currents without heterodyne, we can hope to eliminate at least partially the recording of atmospherics. In an auxiliary receiver detuned from the incoming wave we can receive alone the same atmospherics as those which appear in the main reception, and can thus, as has already been shown, arrange the two records in opposition in order to obtain a single record of the signals. In order to obtain the same results with the heterodyne, we must use a supplementary detector to recover the continuous current. Besides being more complicated

* French Patent No. 502041, February 11th, 1915.

† See French Patent No. 493924.

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we lose when using this method the advantages of the sensitiveness of the other.

Another mode of reception comparable with the heterodyne as regards the elimination of strays, is that based on the modulation of the transmitter at low frequencies in order to render the signals directly audible after detection. M. Bethenod in 1908 suggested the use of a high frequency alternator excited by a low frequency alternating current. This excitation, on which we can advantageously superimpose a continuous current excitation (such as we have elsewhere suggested) can only be adopted in certain types of alternators having laminated inductors. Another means of modulating the transmitted current consists in introducing into the antenna circuit a reactance or inductance which can be varied. Messrs. Leonard and Weber in *L'Éclairage Électrique* of July 21st, 1906, suggested using the variation in the permeability of iron with its degree of saturation, not only to double the frequency of an alternating current with two transformers in accordance with the now well-known scheme, but also to vary at will the reactance of an iron-cored inductance, by more or less saturating its magnetic circuit by means of an auxiliary current. This arrangement, recently revived by different inventors, has been called a magnetic amplifier by Alexanderson. Fig. 5 gives a diagram of an antenna circuit including a variable inductance on the lines suggested in French Patent 501473. A central coil A is included in the antenna circuit, and the current for controlling the magnetic state of the iron is passed through the side coils BB. If these lateral coils are traversed by an alternating current at low frequency, the maximum values of which saturate the magnetic circuit, the radiation will be modulated at twice the frequency of the alternating current. But as we have said, by superimposing a direct current on this alternating current the modulation can be effected at the same frequency. We have also suggested making a variable inductance by mechanical means by inserting a small variable reluctance alternator in series in the antenna.

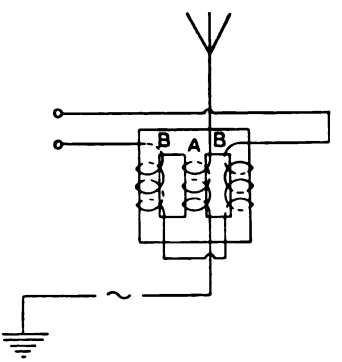

FIG. 5.

By all these methods we can obtain a high frequency transmission of $I \sin \omega t$, of which the strength varies periodically at low frequency corresponding to a pulsation α. The transmitted current will be $I \sin \omega t\,(1 - \sin \alpha t)$; it will pass through a maximum of $2I$ and a minimum of 0. The received current at low frequency with a detector which rectifies the high frequency current perfectly, will always be proportional to $2I$.

At the same time we can see the amount of energy supplied by the local generator or heterodyne in beat reception, and how much less can theoretically be used at the transmitter for the same signal strength. Using an ideal rectifier we should obtain the same telephone current in heterodyne

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reception as with the modulated transmission indicated above, in which the maximum value of the steady high frequency current is I. The heterodyne generator, if we compare the extreme instants where the local current and the received current are in phase and in opposition respectively, will be well within these conditions, and the effect will be the same as if the transmission were of intensity $2I$. In these two cases the energy in the antenna will be in the ratio of $\frac{3}{2}$: 1 to produce equal effects in the receiver.

The reduction of power thus possible for a given signal strength using the heterodyne, though appreciable is far from being such as to be able to explain the great sensitiveness of this method of reception for weak signals, as several authors have claimed. As we have already said, the fundamental cause depends essentially on the modification of the rectifying properties of the detectors, when the strength of the high frequency current to be rectified is increased. It would therefore seem that modulation of the transmission ought to be the better method.

In practice in heterodyne reception, the musical note is determined at the receiving station by the frequency of the local generator itself. It is not a characteristic of the transmitting station. In modulated transmission on the contrary, the received note is a characteristic of the transmitter itself.

If we assume in the first case that a strong atmospheric discharge makes the antenna vibrate at the frequency to which it is tuned, that is to say at the frequency of the transmitting station, for a time long enough to produce beats, this discharge will of itself give rise in the receiver to the same note as that given by the transmitter. Doubtless the possibilities of this phenomenon will be reduced by receiving on a low note, as an oscillatory discharge must then last longer in order to give the same note as that of the transmitting station. The phenomenon is, however, always likely to occur.

On the contrary in the case where the note is formed by the modulation of the transmitted current no discharge will be able to give rise to a note identical with that of the transmitter. We must therefore conclude that acoustic resonance to the received note should be more useful for protection against atmospherics when the note is given by the transmitting station itself than when it is obtained by means of a local heterodyne. Doubtless future experiments will bring out this point.

Hence although we have shown the extraordinary sensitivity of the heterodyne and detector system for weak signals, we feel that we must conclude this paper with some degree of reservation as to the future of this system.

We have received a letter from M. Latour in which he points out that the term "wire radio" should be replaced by the more appropriate one "high frequency telephony and telegraphy." This system is older than radio-telegraphy, having been invented by M. Maurice Leblanc in 1891 and 1893 (French Patents 215901 and 239785). The use of power lines for high frequency telegraphy is described by Neu in French Patent 355442 of 1905.—ED.

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The Breakdown and Protection of High Voltage D.C. Machines supplying Spark Transmitters.*

By K. W. WAGNER.

High-voltage D.C. machines were first used in spark transmitting stations by Marconi, who installed them at Clifden and Glace Bay. The diagram of connections is shown in Fig. 1. The battery B was installed to protect the dynamo from breakdown due to the spark gap. This battery, which proved expensive and troublesome, was removed and the inductance of the dynamo reduced by compensating windings. Fig. 2 illustrates an arrangement due to Lepel, which was in use for some time at Königswusterhausen. There are two sets of gaps in series, a rotating set at UU_1 and a quenched set at F. There are two condensers C, C_2 of which the latter is so connected to the rotating gap that it is reversed between successive sparks as shown diagram-

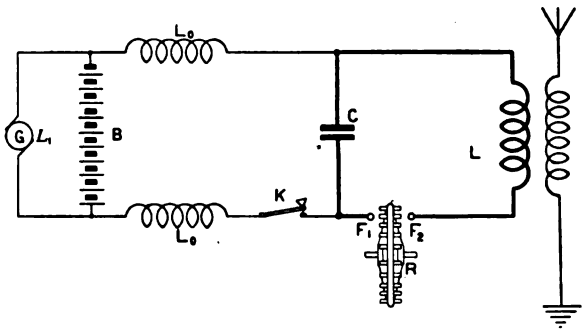

FIG. 1.

matically in Fig. 2. The rotating gap acts as a reversing commutator. Arcing is here impossible since the circuit is never closed except through condensers. At the end of a discharge C and C_2 have equal voltages, during the succeeding interval C is charged to a higher voltage from the source whilst C_2 is reversed so that when the next spark occurs the voltages of C and C_2 are added. The current from the dynamo is thus stored in C until a spark occurs when C shares its charge with C_2; the charge of C_2 is then transferred from U to U_1 by the rotation of the commutator. The aerial is coupled to the coil L in the usual manner. The sending key K is shunted by a condenser C_n in series with a damping resistance to prevent damage to the contacts of the key by the discharge of C_n. C_1 represents a protective condenser if such be employed; if not it may be taken to represent the self-capacity of the dynamo. The first high-voltage dynamo employed broke down and was replaced by a 10,000-volt machine belonging to the Reichsanstalt which also broke down after a very short time. No protective

* Abstracted from the *Elektrotechnische Zeitschrift*, July and August, 1920. See RADIO REVIEW Abstract No. 1388 in this issue.

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condenser C_1 was employed. The failure of these two machines led to investigations as to the nature of the phenomena accompanying the discharges in the spark gap circuit. Calculations and tests agreed that the cause of the breakdown lay in the resonance of the whole charging circuit, consisting of the dynamo, the two choke coils L_0 L_0 and the main condenser C. It was also found that unless the key condenser C_u had a greater capacity than the main condenser C the greatest danger arose on opening the key.

The charging of the condenser C is oscillatory; assuming the capacity C to be $\frac{1}{3}$ μF, the inductance L_1 of the dynamo to be 24 H and the combined inductance L_2 of the choke coils to be 36 H, the resonant frequency is found to be 35·6 cycles per second. The self-capacity of the dynamo is negligible in this connection. As the rotating commutator gave 250 sparks per second,

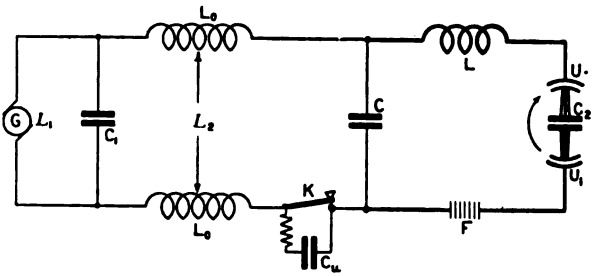

FIG. 2.

the charge occupied but a fraction of the resonant period of the charging circuit. (In the Marconi arrangement, on the other hand, it is customary to tune the charging circuit to resonance with the periodic discharge.) The spark discharge occupies a very short time during which the dynamo current cannot change appreciably; hence this current must have the same value at the beginning and end of the charging interval during which the current passes over the crest of its curve as shown in the upper part of Fig. 3. The voltage of C increases from V_e to V_a, then the spark occurs and C shares its charge with C_2 which still has a voltage of V_e but reversed. This reduces both to V_e, hence if C and C_2 have equal capacities as was the case $V_a - V_e = 2V_e$ and $V_a = 3V_e$. In the actual case V_a was 12,000 and V_e 4,000 volts. The voltage across C has therefore the saw-tooth wave-form shown in Fig. 3. If drawn to a larger scale, however, the vertical lines would be replaced by short intervals equal to the duration of the spark during which the voltage makes a damped oscillation as shown in Fig. 4. These sudden changes in the P.D. across C cause surges to travel along the choke coils in so far as their inductance is short-circuited by their capacity. The best method to protect the dynamo from the surges is to use air-core choke coils of small capacity to earth. This is preferable to the use of a large condenser shunted across the dynamo.

The P.D. of saw-tooth wave-form between the terminals of C contains very strong harmonics, some of which may cause resonance with the natural frequency of the circuit made up of the self-capacity of the dynamo winding

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together with the inductance of the dynamo and in parallel thereto the path through the choke coils and C, which has such a large capacity compared with C_1 that it may be regarded as a short circuit. The capacity C_1 can therefore discharge through two paths in parallel, viz., the generator ($L_1 =$ 24 H) and the choke coils ($L_2 = 36$ H). With no condenser connected across the dynamo terminals C_1 is due entirely to self-capacity and is estimated at $0{\cdot}875.10^{-8}$ F. This gives a resonant frequency of 450 which is dangerously near the frequency of the second harmonic, since the spark frequency was taken up to a maximum of 250 per second. The amplitude of the nth harmonic of the saw-tooth diagram in Fig. 3 is given by the equation—

$$E_n = \frac{E}{n\pi}.$$

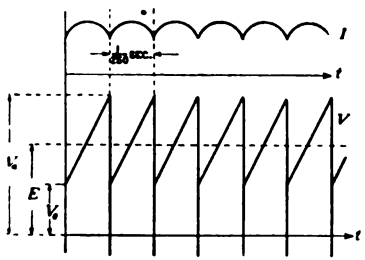

FIG. 3.

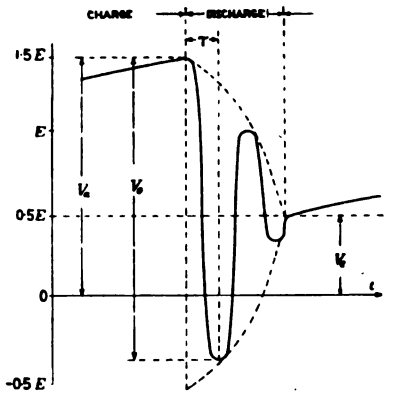

FIG. 4.

With an estimated value of 9,000 ohms for the effective resistance of the oscillatory system, it is possible to calculate the amplitude of the voltage due to the second harmonic, the value obtained is 14,500 V, which superposed upon the continuous pressure of 8,000 V gives a total of 22,500 V.

Another cause of excessive voltage is the sudden opening of the circuit on releasing the key K. The energy stored in the magnetic fields of L_1 and L_2 surges into the condensers C_1 and C_u thereby charging them to excessive pressures unless C_u is of sufficient capacity. At Königswusterhausen C_u was equal to $2C$ and it can be shown that this is ample to guard against trouble from this cause.

A model was made up to test the conclusions by means of an oscillograph; the results agreed with the calculations.

Two devices are suggested for minimising the effects of resonance. The first consists in connecting two condensers in parallel across the machine terminals with a resistance, however, in series with one of them. The latter absorbs energy and limits resonance effects, whilst the former prevents sudden pressure rises due to steep-fronted waves transmitted back from the spark gap. The second device which may be used alone or in conjunction with the first consists in shunting a portion of one of the choke coils with a suitable resistance; the same result can be obtained by putting the resistance across an independent winding on the same iron core as the choke coil, or

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even by making the core solid and utilising the eddy current losses as a means of damping.

According to Lepel who was in charge of the station at the time, the breakdown of both machines was due to a very simple fault, viz., to the breaking down of the insulation of the air-cored choke coils thus subjecting the machines to the effects of the spark gap with no protection beyond the iron-cored choke coils the capacity of which was too great to make them effective as a protection against the sudden changes of potential.

[In a paper in the *Archiv für Elektrotechnik* * Rogowski has published a mathematical investigation into the causes of the same breakdown. He disagrees with Lepel's explanation and maintains that the breakdown of the insulation of the armature was due entirely to resonance phenomena.—ED.]

Electrical Measurements at Ultra-Radio Frequencies.†

By G. C. SOUTHWORTH, M.S.

INTRODUCTION.

In a previous paper‡ sources of alternating currents of ultra-radio frequencies were described. Methods were also given for measuring the length of standing waves produced on a parallel wire circuit when excited by a very high frequency source. The sharpness of resonance obtained for this type of tuning suggests that various other electrical measurements may be made with a similar accuracy. This as we shall see is true. The methods involved are similar to those used by Drude§ in measuring the dielectric constant of liquids but are simpler and more accurate because of the use of continuous oscillations.

Measurements at radio frequencies are usually made in simple circuits consisting of localised inductance and capacity with the resistance reduced to a minimum. A determination of frequency merely consists of adjusting the circuit to resonance with the impressed E.M.F. and computing the frequency from known circuit constants. This condition of resonance is sometimes expressed in terms of the length of the wave that would be radiated at that frequency.

Determinations of inductance and capacity are made by forming resonant circuits involving the unknown coil or condenser. Later an adjustable standard replaces the unknown and the resonant condition is reproduced. This requires that suitable standards be maintained. Standards of capacity when properly constructed may be calibrated at low frequency, and this calibration may be assumed to hold for radio frequencies. A coil on the other

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* *Archiv für Elektrotechnik*, 9, p. 191, September, 1920. (Abstract No. 1387 in this issue.)

† Received November 9th, 1920. ‡ RADIO REVIEW, 1, pp. 577—584, September, 1920.

§ *Wiedemanns Annalen*, 61, p. 466 (1897).

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hand possesses other properties than inductance which cause its calibration to change with frequency. The coils used as standards of inductance are compared with a calculable inductance consisting of a square several metres on a side.* After making corrections for distributed capacity, the various coils are cross checked when used in circuits involving condensers of known capacity. There are many objections to these standards of inductance, but up to the present time no better scheme has been proposed.

The damped sources of current formerly used permitted of radio measurements with errors of about 5 per cent. The use of the electron tube generator now enables such measurements to be made with errors of less than 1 per cent. In all cases radio measurements require a great amount of care and skill in eliminating the various errors. At frequencies of about 3×10^6, corresponding to a wavelength of 100 metres, measurements in circuits having lumped constants become very difficult. This is due to the necessarily small dimensions of the coils and condensers used and the uncertain distribution of the stray inductances and capacities introduced by lead wires and instrument cases. The measurements may however be made in a parallel wire circuit at all the frequencies from those used in radio to the highest yet obtained with the electron tube.

THEORY OF PARALLEL WIRE CIRCUITS.

In order to show that measurements of inductance and capacity may be made in circuits having distributed constants it is necessary to investigate the properties of such circuits (Fig. 1).

The method of treating them can only be outlined here.

Designating the inductance, capacity, and resistance per unit length by L_1, C_1 and R_1, we obtain for the fundamental differential equations

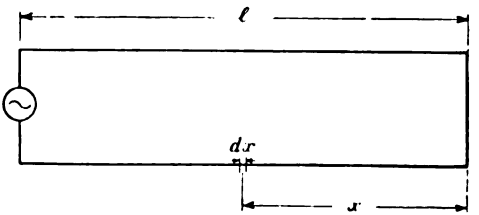

FIG. 1.

$$L_1 \frac{di}{dt} + R_1 i = -\frac{dv}{dx}$$

$$C_1 \frac{dv}{dt} = -\frac{di}{dx}$$

Assuming a sinusoidal voltage and current, these equations reduce to

$$L_1 j\omega i + R_1 i = -\frac{dv}{dx}$$

$$C_1 j\omega v = -\frac{di}{dx}$$

which after differentiating and separating the variables become

$$\frac{d^2v}{dx^2} = p^2 v \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

* U.S. Bureau of Standards Circular 74, p. 100.

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$$\frac{d^2i}{dx^2} = p^2 i \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where $p^2 = j\omega C_1(j\omega L_1 + R_1)$.

The solutions of equations (1) and (2) are

$$i = A\epsilon^{px} + B\epsilon^{-px} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and

$$v = \frac{p}{C_1 j\omega}\left\{A\epsilon^{px} - B\epsilon^{-px}\right\} \quad . \quad . \quad . \quad (4)$$

where A and B are constants determined by the boundary conditions and p is the propagation constant which consists of a velocity constant

$$\beta = \sqrt{\omega^2 L_1 C_1 + \frac{R_1^2 C_1}{4L_1}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

and an attenuation constant

$$\alpha = \frac{R_1}{2}\sqrt{\frac{C_1}{L_1}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

such that $p = \alpha + j\beta$.

To find the values of A and B we must state boundary conditions. The method is applicable to the case of a line with open or closed ends. In the case of a line with closed end—

when $x = 0$, $v = 0$, and $A = B$.

When $x = l$, $v = E$

and

$$E = \frac{p}{C_1 j\omega}\left\{A\epsilon^{pl} - B\epsilon^{-pl}\right\}$$

or

$$B = A = \frac{EC_1 j\omega}{p}\left\{\frac{1}{\epsilon^{pl} - \epsilon^{-pl}}\right\}.$$

Hence

$$i = \frac{EC_1 j\omega}{p}\left\{\frac{\epsilon^{px} + \epsilon^{-px}}{\epsilon^{pl} - \epsilon^{-pl}}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

which reduces to

$$i = \frac{EC_1\omega}{\sqrt{\alpha^2 + \beta^2}}\sqrt{\frac{1 + \cos 2\beta x}{1 - \cos 2\beta l}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

if the attenuation constant be neglected.

The periodic time function has been omitted because we are concerned only with the amplitude. Equation (8) shows the current distribution along the conductor as well as the maximum current for any adjustment of l.

When x is so chosen that $\cos 2\beta x = \cos 2\beta l$

$$i = \frac{E\omega C_1}{\sqrt{\alpha^2 + \beta^2}}\cot \beta l \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Taking $\frac{i}{E} = Z$ we get

$$Z = \frac{\omega C_1}{\sqrt{\alpha^2 + \beta^2}}\tan \beta l \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

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Substituting the approximate values of α and β in equations (5) and (6), it follows that

$$Z = X = \sqrt{\frac{L_1}{C_1}} \tan l\omega\sqrt{C_1L_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

is the effective reactance for the point $x = l$.

It may also be shown that for an open end line

$$X = -\sqrt{\frac{L_1}{C_1}} \cot l\omega\sqrt{C_1L_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

Plotting $X = \sqrt{\frac{L_1}{C_1}} \tan l\omega\sqrt{L_1C_1}$, we obtain the familiar tangent curves shown in Fig. 2.

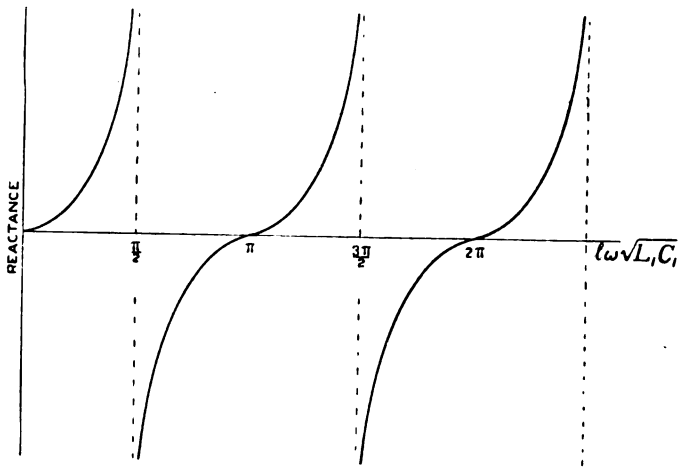

FIG. 2.

If $l\omega\sqrt{C_1L_1} = m\pi$

the wavelength $$\lambda = \frac{2l}{m} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

where m is any integer, since the velocity of propagation $c = \frac{1}{\sqrt{L_1C_1}}$ and $\omega = 2\pi f = \frac{2\pi c}{\lambda}$.

If we place a reactance in the line where $x = l$ we may equate the sum of the reactances to zero to determine the condition of resonance. If it be an inductance,

$$\omega L + \sqrt{\frac{L_1}{C_1}} \tan l\omega\sqrt{L_1C_1} = 0$$

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or $$L = -\frac{\lambda}{2\pi} L_1 \tan \frac{2\pi l'}{\lambda} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

where l' is the length of the wires for resonance after the inductance L has been added. It will be seen that resonance is obtained when the angle $\frac{2\pi l'}{\lambda}$ is measured in the second or fourth quadrants. If $\frac{2\pi l'}{\lambda}$ is small, $L = l'L_1$.

If a condenser be placed in the end of the parallel wire system

$$-\frac{1}{\omega C} + \sqrt{\frac{L_1}{C_1}} \tan l\omega\sqrt{L_1 C_1} = 0$$

or $$C = C_1 \frac{\lambda}{2\pi} \cdot \cot \frac{2\pi l'}{\lambda} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

where C is the capacity of the condenser.

When $\frac{2\pi l'}{\lambda}$ is large $C = l'C_1$. If the length of the parallel wire circuit be so chosen that $m = 1$ and its constants be computed, equations (13), (14) and (15) become

$$\lambda = 2l \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

$$L = -Kl \tan \frac{l'}{l} 180° \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

$$C = K'l \cot \frac{l'}{l} 180° \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

which are convenient for application to measurements. These equations are based on the assumption that the velocity of propagation is independent of the wavelength and is the same as that of light in free space. This is correct if the resistance of the conductors is not too large compared with their inductance and the circuit is so arranged that no materials of high dielectric constant come within its field. By referring to equation (5) above, it will be seen that resistance errors are improbable for frequencies corresponding to wavelengths of one or two metres. At radio frequencies however this effect may be of considerable consequence.

EXPERIMENTAL.

In order to measure inductance or capacity with the apparatus described in the author's previous article, it is necessary to adjust the length of the parallel wires to resonance with the applied E.M.F. This length gives the value of (l) used in the formulæ above. The coil or condenser is then inserted in the end of the line and the circuit again adjusted to resonance. This gives (l'). Substituting these values in equations (17) or (18) the results follow with very little mathematical work.

This method has been used in obtaining data regarding the internal

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capacities of various types of electron tubes. It was found to be exceedingly rapid as well as accurate. If it is desired to measure several small capacities at a single wavelength, each value of (l') may be determined in a few seconds.

An experiment was made to determine the accidental error in measuring wavelength. Twenty independent observations were made with the generator set at a given frequency. The mean result was 188·330 cm. with a mean deviation of 0·050 cm. In order to determine the accidental error in measuring the capacity of a small parallel plate condenser, twenty observations were made at wavelengths varying from 115 to 270 cm. No progressive error could be detected. The result was 3·68 $\mu\mu$F with a mean deviation of 0·07 $\mu\mu$F. The method was applied to the measurement of the capacity between the plate and grid of an electron tube and an interesting progressive error developed as is shown by the table.

Wavelength λ cm.	Apparent capacity C_a $\mu\mu$F.	Corrected capacity C_0 $\mu\mu$F.
169·6	11·72	7·87
176·8	11·54	8·02
188·8	10·40	7·75
223·0	9·71	7·85
231·6	9·61	7·92
233·2	9·45	7·80

The progressive error in the capacity is readily explained by the inductance effect of the lead wires. If we assume it to be the case of an inductance and capacity in series it is equivalent to the reactance of a certain apparent capacity C_a

so that
$$\omega L_0 - \frac{1}{\omega C_0} = -\frac{1}{\omega C_a}$$

or
$$C_a = \frac{C_0}{1 - \omega^2 C_0 L_0}.$$

The third column gives the value of the capacity obtained by correcting the apparent capacity for inductance effects. The inductance necessary to explain this effect would be 0·034 μH. The measured capacity at radio frequencies is 7 $\mu\mu$F. The errors of the radio methods do not permit of any greater accuracy on such small capacities. It may be shown that the apparent capacity would decrease with increase of frequency if there were losses in the dielectric.

Five observations were made on the measurement of the inductance of a small coil of wire. The final result was 0·121 μH with a mean deviation of 0·002 μH.

Measurements of current and resistance have not been investigated, but this problem is not as easily solved. Possibly an expression for resistance may be obtained in terms of the relative sharpness of resonance curves. If standards of resistance are required, such methods will be applicable only to wavelengths greater than perhaps 30 metres ($f = 10^7$) because of the change of resistance of the standards with frequency.

Continuous oscillations have been used to measure the difference in the velocity of propagation along iron wires and those of copper and German

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silver. The dielectric constant of water has also been measured with continuous oscillations by two methods. (In one the capacity of a condenser using water as a dielectric is measured and compared with its capacity when air is the dielectric. By the other method the Lecher system is immersed in a tank of water and the wavelength measured and compared with that for air. In the latter method the resonance points may be located very accurately by noting the changes in the plate current of the generator as the resonance points are approached.)

While the tests of the above methods were made at the shorter wavelengths, it is obvious that it is applicable to the entire range of wavelengths beyond those used in radio; however it would be rather inconvenient to work with a circuit 50 metres in length. It would be especially desirable to extend these methods to the radio frequencies in order to check the so-called standards of wavelength which at present are based on the standards of capacity and inductance described above, as any standard should be arrived at by more than one method. [See Note on p. 1.—ED.]

Yale University. *October 15th*, 1920.
New Haven, Conn., U.S.A.

Inaugural Address to the Wireless Section of the Institution of Electrical Engineers.*

By W. H. ECCLES, D.Sc. (Chairman of the Section).

The address opened with a few remarks concerning the formation of the Wireless Section of the Institution of Electrical Engineers, and continued with a brief review of the papers and lectures delivered before that Section summarising the wartime development of the various branches of radio work. Some of these papers, said Dr. Eccles, provoked a number of inquiries and suggested further research work. Notable among these was one by Mr. B. S. Gossling which described the results of several years' work on thermionic valve development in the Service laboratories.

In the use of these tubes certain results are obtained even in respect of such a fundamental parameter as the voltage factor which have not yet been fully discussed.†

The results of some measurements of voltage factor with varying grid voltage and filament current were shown in the form of curves, and of these an interest-

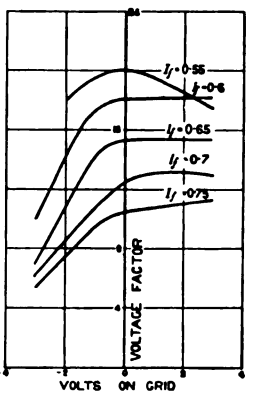

FIG. 1.

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* Address delivered at the opening meeting of the session on Wednesday, November 24th, 1920—abbreviated.

† See RADIO REVIEW, 1, pp. 283—285, March, 1920, for abstract.

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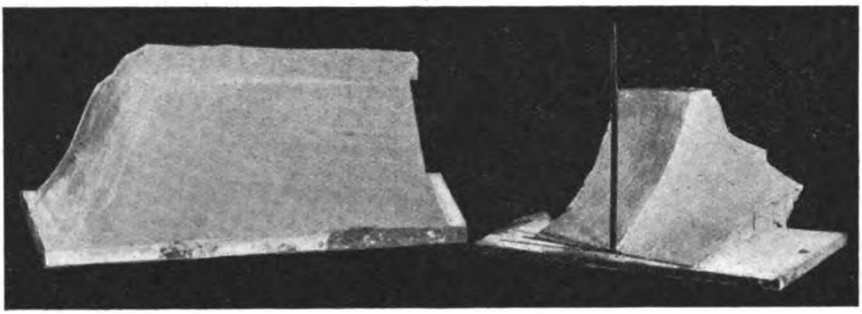

FIG. 2. FIG. 4.

ing series is reproduced in Fig. 1. The reason for the variation of the voltage factor arises out of the unevenness of the temperature of the filament to some extent, but chiefly out of the drop of voltage along the filament.

Curves showing the variation of the average value of the voltage factor as the filament current is altered bear a striking likeness to the curves depicting the results of some measurements made by Dr. Vincent in 1919 on the change of the wavelength of the oscillations generated by a triode under certain conditions. Perhaps these changes owe their origin to variations in the average value of the voltage factor.

Among other insufficiently investigated properties of the triode are those associated with certain portions of the characteristic surfaces which may be used to represent all the principal properties of the tube. When the filament current and voltage are kept constant there remain four principal variables, namely, the anode current i_a, the grid current i_g, the anode voltage e_a, the grid voltage e_g. If we represent anode current and grid current separately each of these must be regarded as a function of the two independent variables e_a and e_g.

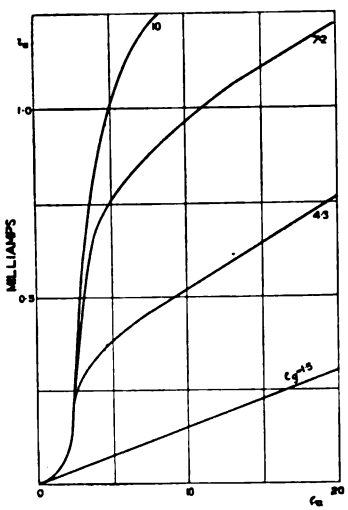

FIG. 3.

These variables may be represented by three axes at right angles, the anode and grid voltages being represented by the two horizontal axes, while the vertical one is used to represent either grid or anode current.

Upon these axes we may erect surfaces to represent the current flowing in a triode at any assigned values of the two voltages by measuring off to scale these voltages along the appropriate axes and erecting at the point so determined a vertical with two ordinates equal in value to the observed

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currents. When this is done we obtain for the anode current such a surface as is shown in the photograph of Fig. 2. The flat top represents the saturation values, the concave sloping surface at the right-hand side follows in the ideal case the three-halves power law, and normally only a small part of this area on the extreme right hand of the picture is utilised. On the left hand where the surface descends in a kind of cliff to the axis of the grid voltage we have a region little investigated and scarcely utilised as yet. This surface was constructed from curves such as those of Fig. 3 which are in fact sections of the surface made by vertical planes parallel to the axis of anode voltage and represent what happens to the anode current, at various constant grid voltages, as the anode voltage is increased. It will be noticed that at low anode voltages the anode current rises very rapidly. In the next figure (Fig. 4), which is a photograph of a model of a grid current surface, it is seen that at low anode voltages the grid current falls rapidly as the anode voltage is increased from zero. On the left hand of the sharp ridge are represented values of grid current when the anode voltage is negative, that is to say when practically no anode current is flowing. The concave sloping part obeys the three-halves power law and the flat top represents saturation. Fig. 5 shows shapes of the grid characteristics from which such a surface as that of Fig. 4 is prepared. All the familiar characteristics seen in books and papers can be obtained from these surfaces by making sections.

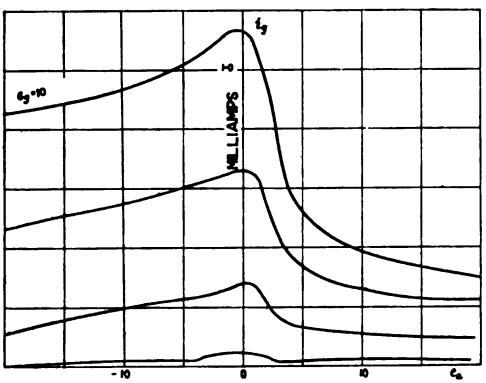

FIG. 5.

The rapid rise of anode current and accompanying fall of grid current in the region of low anode voltages requires explanation.

When the grid is slightly positive and the anode at zero voltage the electrons starting from the cathode with considerable normal velocity may perform wide orbits round the grid wire but are finally drawn into it.

But if the anode is slightly positive many of the electrons not passing too near the grid wire end their career on the anode. It may be shown that the grid current has the value $i_g = A'(e_a + \nu e_g)^{\frac{3}{2}} \exp\{-\alpha\sqrt{(e_a/e_g)}\}$ and that the anode current is given by $\log(1 + i_a/i_g) = \alpha\sqrt{(e_a/e_g)}$ at low voltages, when ν is the voltage factor and A' and α are constants that are different for each tube. For ordinary reception triodes α has the value 1·3 approximately.

These considerations call attention to a fact that does not appear to have received adequate notice, namely that the grid in a triode may exert two

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distinct types of action. The type just described which is characterised by having the bulk of the grid current contributed by electrons that have suffered great lateral deflections, may be called a snatching action ; the other type of action which is that usually utilised in triodes, is of the nature of an acceleration or deceleration of the motion of the electrons from the cathode to the anode ; in brief, one type of action by the grid is mainly a lateral attraction of electrons the other is mainly a longitudinal effect in the direction of motion. The steep surfaces near the axes of grid voltage in Figs. 2 and 4 are due to the snatching action.

In Fig. 6 is shown a surface representing by its ordinates both the grid and anode currents of an ordinary form of triode. It is seen that the snatching action that goes on between the grid and the anode at low anode voltages produces a gully separating the two surfaces. The question immediately arises : What is there beyond the region embraced by this figure ? Very little published information is available for answering this question, but

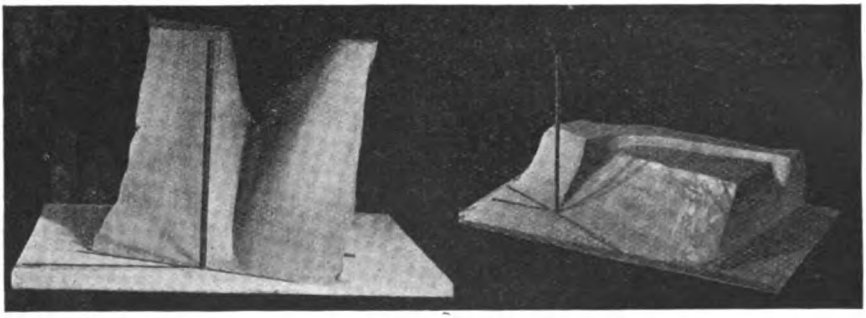

FIG. 6. FIG. 7.

during the past eighteen months I have had parties of students studying the geography of the gully and the plateaux seen in Fig. 6. In particular I have to mention the work of Mr. L. Grinstead and Mr. T. W. Price in this connection. As a result I am able to give in Fig. 7 a photograph of a surface representing most of the properties of ordinary triodes. The gully noticed in the previous figure is seen to take a sharp turn. On the extreme right of the model a section taken at a fixed and fairly high anode voltage is seen, and this section is therefore the characteristic curve of the grid and anode currents as the grid voltage varies. On following the curve of section from front to back the anode current is seen to rise from zero to a maximum as the grid voltage rises to remain nearly constant till the gully is reached and there to descend suddenly ; during this descent the grid current rises and becomes greater than the anode current. The plateau beyond the gully belongs to the grid current. This is not strictly what happens in an ordinary exception triode but certain types of tube give such a surface with fair reactitude. A form of triode described by Major Erskine-Murray gives a characteristic very like that shown by this section of the model.

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Another paper read before this section which was vastly provocative and stimulating was that by Captain H. J. Round on Directive Telegraphy. Captain P. P. Eckersley has suggested that much of the observed directional error might arise from the rotation of the plane of polarisation of the signal bearing waves by reflection at non-level portions of the Heaviside layer between the sending and receiving stations. I am not going to suggest another reason than that just stated for the production of waves with rotated planes of polarisation, but to show the errors caused by such rotation, however produced.

If the ray is represented by a straight rod fixed at an inclination to the horizontal, in the daytime the magnetic force which is perpendicular to this rod is horizontal and the frame will give true directions. For the receiving frame aerial to receive no signals it must be placed so that none of the magnetic force of the waves is linked with it, *i.e.* it must be set so that the direction of the magnetic force of the wave lies in the plane of the coil. But now suppose that at night the plane of polarisation is rotated in any manner, the frame must then be rotated also in order to satisfy the above conditions. That is to say the apparent direction of the source of the radiation, namely, the perpendicular to the frame aerial, is erroneous. It is easily seen that if γ is the error, α the inclination of the ray to the horizontal, and β the rotation of the plane of polarisation, then $\tan \gamma = \sin \alpha \tan \beta$. Thus if it be true that the trajectory of the ray always lies in a vertical plane through both stations, the error in azimuth enables us to compute the angle at which the ray descends to the receiving station. A model was shown to illustrate these effects.

But there still remains the problem of the cause of the rotation of the plane of polarisation. Those who have thought about the behaviour of an ionised atmosphere towards electric waves passing through it will see at once that the earth's magnetic field will introduce obliquity into the motion of ions propelled by the electric force of the waves. Waves passing over any particular ion evidently impart to it a to and fro motion of the same period as that of the waves but lagging behind the electric force of the waves by about a quarter period on account of inertia. The question is: What magnitude of magnetic field is required to produce an oblique component of velocity of the same order of magnitude as that produced by the electric force of the waves? On taking the case of an oxygen ion I find that a magnetic field of 1,700 C.G.S. units is required; for a hydrogen atom 100 units, for an electron 0·06 unit. Now the earth's magnetic field at the surface has a horizontal component of about 0·18 unit. Therefore if I have made no mistake in the arithmetic, a rotation such as is demanded by the observed facts of directive wireless telegraphy could be furnished by the passage of the waves through a space containing free electrons.

If part of the primary waves from the sending station get through to the receiver as well as those which have travelled through the upper levels of the atmosphere, the minimum will be ill marked—in fact the simultaneous reception of the primary waves and the secondary waves in time quadrature will be equivalent to reception of elliptically polarised waves. Leaving

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aside the primary wave, which does not necessarily cause any directional error, we can show that waves travelling from the south through a high layer of free electrons should give rise to a westerly error if the above conclusions are correct, waves from the north give also a westerly error; waves from the east and from the west give southerly errors. It ought to be possible to test these conclusions by observations.

The velocity gained by an electron in waves of the same field intensity is greater the lower the frequency. Thus long waves should give greater directional errors than short waves.

The information gained from observations made with directive aerials must be combined with the knowledge furnished by the analysis of the records of magnetic variations and magnetic storms. Magnetic storms are considered by Professor Chapman to be mainly due to currents in the auroral layers, and these never come lower than about 100 km. Below this is a layer about 50 km thick in which flow the currents causing much of the diurnal variation of the magnetic elements. Professor Chapman suggested that the auroral layer was conducting chiefly because of the presence of alpha particles that had come from the sun; I think that wireless investigators would suggest that the layer beneath the auroral layer is occupied by electrons that have come as beta rays from the sun.

It would seem that the base of this region charged with free electrons must be regarded as the ceiling usually known as the Heaviside layer. I suggest that the diurnally ionised layer below about 50 km is ionised by the gamma rays and other ultra-violet rays from the sun and involves the splitting of electrons from molecules to make positive ions; and at the gas pressures in fairly low levels many of the electrons will combine with neutral molecules to form negative ions. Both positive and negative ions of molecular size give rise to ionic refraction and the arched trajectory of the Hertzian rays, and incidentally to absorption also. Professor Watson's solution of the daylight propagation problem takes account at least partially of such a layer of conducting gas and from his result we may deduce that if the ionisation is effective down to 25 km the conductivity need not be a quarter as great as that of sea-water in order to ensure results such as are summarised in the Austen-Cohen empirical formula.

Dr. Graham Bell, whom we are so glad to welcome here to-night, has told us that this section of the Institution represents to him the advance guard of the British electrical world. It seems to me that in our subject we live nearer the growing edge of electrical science than in other branches of engineering. There is infinite scope for knowledge, discovery, invention and imagination; and I am delighted to know that Dr. Graham Bell is also of that opinion.

And along some of the avenues of our particular technology we may catch glimpses of the radiant expanse of the dawning electrical age. The thermionic vacuum tube in itself contains for the engineer of vision some of the most resplendent of these vistas. For from the glowing filament the most subtile and potent of all the gases is evaporated, namely, the gas made up of pure electrons, a gas we cannot at present harness as easily as steam is

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harnessed, but which must take its turn as a servant of man. And in those future days strange engines of giant strength, utilising electrostatic forces and thermodynamic cyclics as yet unimagined, will be fed with electrons urged by millions of volts along vacuous conduits and will be presided over by matterless switches. And the people of that age will look back and wonder why we in the twilight of the age of steam were so long content to poke slow floods of electricity through the crowded atoms of copper cables.

Wireless Telegraphic Printing on the Creed Automatic System.*

By A. A. CAMPBELL SWINTON, F.R.S.

So far as the purely wireless instruments used for this demonstration are concerned they are nothing very special. We have a small aerial on the roof of the building, and connected to this through the ordinary tuning inductance and adjustable condenser there is a five-valve resistance amplifier working in conjunction with a three-valve transformer coupled note-magnifier, to which the telephones and other apparatus is connected. This latter consists firstly of a low frequency transformer connected to the grid of a separate single valve which has a 15-volt battery connected in its grid circuit to maintain the grid potential at a suitable negative value. In the plate circuit of this valve is a special relay designed by Mr. R. Carpenter of Messrs. Creed and Company, Ltd., which is connected to a standard P.O. relay through two resistances each of about 1,000 ohms. This P.O. relay in turn operates a power relay also of Mr. Carpenter's design. This last relay has no electrical contacts but its tongue operates directly the pneumatic slide valve of the

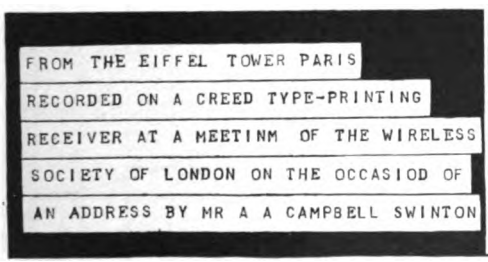
FROM THE EIFFEL TOWER PARIS
RECORDED ON A CREED TYPE-PRINTING
RECEIVER AT A MEETINM OF THE WIRELESS
SOCIETY OF LONDON ON THE OCCASIOD OF
AN ADDRESS BY MR A A CAMPBELL SWINTON

FIG. 1.

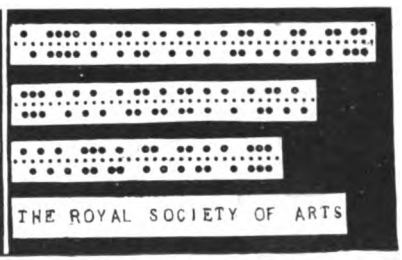

FIG. 2.

Creed receiver to control the air supplied to a small cylinder the piston of which is therefore moved from side to side in accordance with the signals which actuate the relay tongue. The movements of this piston are transmitted by means of suitable mechanism to the valve controlling the double-acting piston of the main tape punching mechanism. The incoming wireless

* Abstract of paper read before the Wireless Society of London on November 18th, 1920.

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signals are thus amplified up sufficiently to operate the mechanism of this punching machine and enable the message to be taken down in the form of an ordinary Wheatstone type of punched strip.

The remainder of the paper was devoted to an illustrated description of the slip perforating mechanism and of the printing machine through which the slip is subsequently passed in order to yield the final message printed in Roman characters.

A special message was sent from the Eiffel Tower, Paris, which was picked up by the apparatus at the meeting and taken down on the strip. A portion of this message as actually received is reproduced in Fig. 1, while in Fig. 2 is a sample of another portion of strip received on the instrument showing both the punched strip and the final strip printed in Roman characters.

A Four-electrode Thermionic Detector for Damped or Undamped Electric Oscillations of High or Low Frequency.*

By J. A. FLEMING, M.A., D.Sc., F.R.S.

The various forms of radio wave generator now in use give us three types of wave radiation with a great range of wavelength. It seemed to me therefore that it would be interesting to endeavour to design a simple thermionic detector and receiving arrangement which should be quite independent of the nature of the transmitter, and detect without change of apparatus or circuits undamped as well as damped waves of any wavelength. The following is a description of the construction of a four-electrode thermionic detector which

FIG. 1.

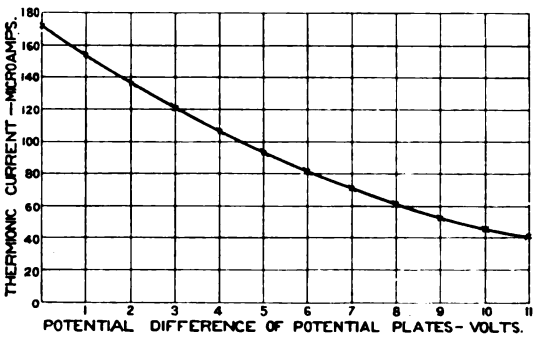

FIG. 2.

I have found efficient for this purpose. While not approaching the sensitivity of the cascaded three-electrode amplifier it yet has some special advantages of its own. In a glass bulb 3 inches in diameter a short straight vertical tungsten filament about $1\frac{1}{4}$ inches long is mounted. This filament

* Abstract of paper read before the Wireless Society of London on December 10th, 1920. (See also p. 1 of this issue.)

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is kept straight by a small spiral spring. Around the filament are arranged four narrow curved nickel plates about 1¼ inches long by ¼ inch wide slightly curved about their long axis and set with convex faces towards the filament and 2 or 3 mm. from it. One pair of these plates, on opposite sides of the filament, which I refer to as the "potential plates," are connected to separate wires led out to the terminals of the bulb. The two remaining plates are connected together and to a fifth leading in wire. These plates are called the "collecting plates." The bulb is exhausted and the electrodes freed from gas in the usual manner employed in making hard valves. Fig. 1 shows the general appearance of the valve.

The peculiar property of this thermionic detector is that if a small difference of potential whether of high or low frequency is set up between the potential plates the thermionic current passing between the filament and the collecting plates at once falls to an extent determined by this potential difference. We can therefore describe a characteristic curve by plotting the thermionic current to the collecting plates against the potential difference applied to the potential plates. Such a curve is shown in Fig. 2.

To use this device as a detector in wireless reception we need only connect the potential plates to the terminals of the tuning condenser in the closed receiving circuit and insert in the external plate—filament circuit of the valve some current detecting instrument which will indicate the change in the thermionic current. When so used the arrangement is about as sensitive as a simple crystal detector.

If we insert in the plate—filament circuit an ordinary telegraph relay (Fig. 3) the commencement of each received signal will cause the relay contacts to open.

In order to increase the sensitiveness of the arrangement it is evidently necessary that the potential difference between the potential plates shall be made as large as possible. We can achieve this to some extent by arranging the receiving circuit so that its capacity is small and inductance large. We can also amplify to some extent by the use of resonance spirals.* I may say I have not yet had time to determine the effect of a slight reduction of the vacuum upon the performance of this valve. By this means the thermionic currents could be increased while there should be little danger of shortening the life of the filament by positive ion bombardment since the potential of the anode plates is only a few volts.

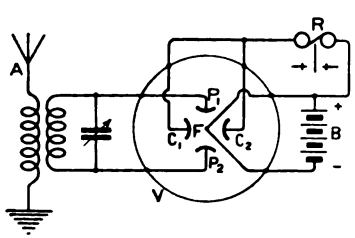

FIG. 3.

In connection with this subject a very simple type of bell call has been devised. It depends upon the insertion of an inertia relay in the plate-filament circuit of a valve of this type so that the call bell's contacts will not be closed unless the current through the relay is kept going without interruption for a couple

* See RADIO REVIEW Abstracts No. 854, September, 1920, and No. 1392 in this issue for references to the uses of these spirals.

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of seconds or so. The intermittent currents due to Morse signals will not last sufficiently long to cause the bell to ring.

I have not attempted as yet to make comparisons between the four-electrode valve and other detectors as regards sensitivity but from a few tests it appears to be about as sensitive as a good crystal detector. Even if it does not invade the field at present occupied by the three-electrode valve it may prove to be a useful adjunct. The valve will also have some laboratory uses for detecting small potential differences in alternating current bridge circuits. Again, we may use this valve to make an alternating current ammeter by connecting the potential plates to the secondary terminals of a transformer through the primary of which is passed the high or low frequency current to be measured. The thermionic current through the valve will be diminished to an extent which depends upon its alternating current. I think, therefore, that this four-electrode valve will prove to be of use in our laboratory measurements in addition to any applications in radio work.

Notes.

Personal.

Senatore Guglielmo Marconi, who is decorated with the " Ordine Civile " of Savoy, has been nominated by the King of Italy, on the proposal of Signor Giolitti, to be a member of the Supreme Council of the same Order. [1664]

Professor E. Branly, Membre de l'Institut, who is well known in connection with the early discoveries of coherer action, has recently been promoted to the grade of Officer of the Legion of Honour. Professor Branly was elected a Chevalier of the Legion of Honour in 1900. [1660]

Mr. G. C. Allingham, M.B.E., M.I.E.E., who was until recently chief engineer of the Tudor Accumulator Co., Ltd., has joined the staff of Mr. C. F. Elwell, Radio Engineer, Craven House, Kingsway, W.C. 2. [800]

Mr. A. E. Grocott, late of Marconi's Wireless Telegraph Company, Limited, has been appointed Telephone, Telegraph and Radio Engineer to the Siamese Government. [1665]

Commercial.

The French Government has just signed with the Cie. Générale de Télégraphie sans Fil a contract under which this company is authorised to establish wireless telegraph services for commercial traffic between France and all other countries of the world. The State will receive a share in the net profits after the shareholders have received a fair interest upon the capital of the company. The company has commenced the construction of two large radio-telegraphic centres which will be installed in the neighbourhood of Paris—one to be allocated to trans-oceanic communications, and the other to communications with European countries. [1667]

The recent consolidation of radio interests of the Radio Corporation of America and the General Electric Company in the United States has been followed by a merger between the Marconi Wireless Telegraph Company of Canada and the Canadian General Electric Company — a separate company from the American General Electric Company.

The officers and directors of the new organisation are: Frederic Nicholls, President; G. Marconi, A. E. Dyment and Robert Bickerdike, Vice-presidents: A. H. Morse, Managing Director: and, on the Board, Sir William MacKenzie, Godfrey C. Isaacs, G. M. Bosworth and C. G. Greenshields. Messrs. Nicholls, MacKenzie and Dyment are directors of the Canadian General Electric Company. [1677]

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According to information from Pekin, negotiations between the Chinese War Office and Marconi's Wireless Telegraph Co. of England for a loan of £13,000,000 for the establishment of fifty wireless stations are now practically concluded. Owing to opposition of the Navy Department, however, there is some doubt whether the agreement will be finally signed and made effective.

Legal.—The most important recent change in legislation affecting radio working is the issue of a decree by the Belgian Minister of Railways, Marine, Posts and Telegraphs, setting forth the conditions regulating the establishment and working of receiving wireless stations for other than ordinary commercial uses. The details of this decree are as follows :—

Article 1.—Requests for authorisation must be addressed to the Director-General of Telegraphs and Telephones at Brussels.

The person making the request must indicate the precise place and functions of the proposed station and must furnish for approval a description of the apparatus.

The applicant must prove if such should be the case that he is of Belgian nationality.

Article 2.—Authorisation is granted :—

(*a*) By the Director-General of Telegraphs and Telephones when the applicant be of Belgian nationality.

(*b*) By the Minister of Railways, Marine, Posts and Telegraphs to whom the request should be transmitted by the Director-General, with his advice, if the applicant be a foreign subject.

Article 3.—The station authorised will be utilised exclusively for reception of time and weather signals ; the transmission of any other electrical signal is formally prohibited.

The use of amplifying valves is not allowed. However, the Administration of Telegraphs and Telephones may, in certain particular cases, which must be submitted for approval and after inquiry and examination of the reasons given by the applicant, grant an authorisation to use such apparatus under conditions to be determined by the Administration.

Article 4.—Under the penalty of immediate withdrawal of the authorisation, the applicant must scrupulously observe, and cause others to so observe, the secrecy of any information which is not intended for public use.

The contents of radiotelegrams other than meteorological telegrams which will eventually be received by the postal authorities, must be neither written nor divulged to any one outside the officials appointed by the Administration of Telegraphs and Telephones, or of the judicial authority. The withdrawal of the authorisation as a result of a contravention of this law, will be eventually carried out without prejudice to the applicant of any punishment provided for by law.

Article 5.—The applicant is forbidden to receive any payment or remuneration whatsoever for the reception of information by means of the station authorised.

Article 6.—The Government reserves to itself the right to examine installations authorised. When necessary the applicant will grant to the duly commissioned delegates of the Government free access to the said installations, and will facilitate by every means in his power such examination by the delegates.

Article 7.—The applicant alone is responsible for all consequences whatsoever, resulting from the present authorisation, not only from the point of view of mistakes which may be made, but also in regard to all matters connected with patent rights or of any other rights of a third party. The responsibility of the State is, and will remain, entirely separate in connection with the present authorisation.

Article 8.—The applicant is held responsible for notifying the Director-General of Telegraphs and Telephones of all alterations which he proposes to make to his apparatus. This must not be changed without the previously-obtained consent of the Administration of Telegraphs and Telephones.

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This Administration may however, at any time and for whatever cause, suspend or revoke the authorisations granted, without the payment of any indemnity whatsoever or without giving any reason for such suspension or revocation.

This permission does not include any privilege either for this particular authorisation or for any subsequent authorisation of the same nature.

It is not transferable without the express permission in writing of the Administration of Telegraphs and Telephones.

At the request of the Administration of Telegraphs and Telephones the applicant must immediately place his apparatus out of working order.

Article 9.—The applicant must hold himself responsible for all expenses and charges whatsoever, occasioned by the permission granted to him.

Article 10.—The applicant will pay a fixed annual fee of 20 francs for every authorised receiving station.

The first payment will be made before obtaining the authorisation; it will cover the remainder of any year from the day of the authorisation to the following December 31st.

Subsequent fees will be paid during the month of January of each year. No refund will be made by the Treasury no matter for what reason the use of the apparatus previously authorised be discontinued.

This applies equally in the case of the station being discontinued by order of the Administration of Telegraphs and Telephones.

Article 11.—Stamp duties and subsequent registration fees will be charged to the applicant. [1866]

A change in the wavelength authorised for ship direction finding work has recently been made as regards the Canadian direction finding stations. A notice issued to the masters of merchant ships fitted with radio apparatus drawing attention to this change is as follows :—

On and after August 1st, 1920, the Canadian Radiotelegraph Direction Finding Stations at Chebucto Head, N.S., Canso, N.S., and Cape Race, Newfoundland, will use the wavelength of 800 metres exclusively for transmission and reception.

It will be necessary for all ships to have their transmitters adjusted to transmit on 800 metres if they desire to obtain bearings from the above stations.

All use of the wavelength of 600 metres by Canadian D.F. stations will be discontinued after August 1st, 1920. [1867]

General.

Notice has been given of a decree recently issued by the Soviet Government authorising the installation of a new high-power radio station in the neighbourhood of Chatoursk for ensuring continuous communication with America. The station at Tsarskoie-Selo is to be restored for communication with all European stations.—*La T.S.F. Moderne.* [1665]

An announcement has been made in *l'Électricité* of the formation of a Radio Club in France for the study of wireless telegraph problems. It is proposed to establish one or more experimental and research laboratories and workshops which will be at the disposal of members of the club, and to collect together a library of books and periodical publications dealing with radio work. Visits to wireless stations, laboratories and so on are also included in its programme, together with the establishment of suitable relations with similar societies in other countries. The address of the Club is 95, Rue de Monceau, Paris. [1656]

A meeting of the International Commission for Weather Telegraphy was held at the Air Ministry in London during the week, November 22nd—27th, 1920, at which delegates were present from the leading European countries for the purpose of discussing the co-ordination of the meteorological reports issued by wireless from the high-power radio stations of Europe. Agreements were also arrived at upon the codes for reports from ships at sea, and for special aviation reports. [1846]

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Review of Radio Literature.

1. Abstracts of Articles and Patents.

Classification of Abstracts—In Volume I. of the RADIO REVIEW the abstracts of articles and patents included in this section were arranged as far as possible in the order of their subject-matter, although the details of this classification were not indicated. In this and future issues it is intended that the abstracts shall be grouped as far as practicable under leading headings with the idea of indicating to some extent the subject-matter of the article dealt with. A rigid classification of all radio literature is not easily adhered to unless the number of headings available is so large as to be cumbrous, so that with the arrangement that has been adopted the subject-matter of a given article may in certain circumstances probably be included in more than one heading. In the arrangement of the abstracts, therefore, every endeavour will be made to place the abstract in the group to which it refers primarily, while if possible the other classifications will be indicated in the Annual Index. Each of the main groupings into which the abstracts will be divided have been sub-divided into a number of sub-sections, but as a general rule these sub-sections will not be specifically designated in each issue of the RADIO REVIEW, although they will be available for indexing purposes. The following main groupings have been adopted :—

(A) General and descriptive articles on **Radio Stations and Installations,** including notes *re* new stations, etc. (B) **Spark transmitting apparatus,** including descriptions, etc., of the various forms of spark gaps. (C) **Arc apparatus.** (D) **High frequency alternators.** (E) **Static or transformer frequency raisers.** (F) **Thermionic valves** and valve transmitting apparatus, including theory and descriptions of the two and three-electrode valves and valve apparatus. (G) **Transmitter control or modulation** for radiotelegraphy or telephony. (H) **Radio receiving apparatus.** (I) **Amplifiers.** (J) **Subsidiary radio apparatus,** including generators transformers, switchgear, protective apparatus, rectifiers, telephones, materials, etc. (K) **Aerials,** including earthing systems, artificial aerials, masts, etc. (L) **Radio wave transmission,** including theory, experiments, upper atmosphere, etc. (M) **Atmospherics,** including anti-atmospheric devices. (N) **Interference and interference prevention,** including secrecy methods of signalling. (O) **Duplex and multiplex radio communication.** (P) **High-frequency circuits and measurements,** including theory and electric circuits, methods of measurement and measuring apparatus. (Q) **Short wave apparatus,** including applications of very high-frequency oscillations for measuring and other research work. (R) **Radio direction-finding**—descriptions of apparatus, theory of wave deviation, etc. (S) **Distant control by wireless.** (T) **High Frequency Wire Telegraphy and Telephony.** (U) **Miscellaneous methods of communication** other than wire telegraphy and telephony, including light, earth current, submarine and similar methods of communication. (V) **Traffic particulars** of radio stations, and programmes of transmission. (W) **Radio legislation**—laws, patents, agreements and litigation. (X) **Biographical and personal notes.** (Y) **Historical articles.** (Z) **Miscellaneous,** including miscellaneous applications of wireless, books and book reviews, nomenclature, etc.

Radio Stations and Installations (General and Descriptive Articles).

1331. **L. Faljau.** The New Radio Station at Lyons. (*Wireless Age*, 7, pp. 11—14, September, 1920. *Science Abstracts*, 23B, p. 550, Abstract No. 1045, November 30th, 1920—Abstract.)

An illustrated description of the station with some details of the 450 kW arcs and of the Bethenod alternator installed there.

1332. Official Opening of the New Nauen Station. (*Elektrotechnische Zeitschrift*, 41, p. 819, October 14th, 1920.)

An account of the opening on September 29th of the "greatest radio station in the world," in the presence of the President of Germany and many high officials. It has a range of 20,000 km and is used exclusively as a transmitting station the corresponding receiving station in America being at Chatham. In the reverse direction the sending station is at Marion and the receiving station at Geltow near Potsdam.

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1333. **E. E. Bucher.** "WII"—New Brunswick. (*Wireless Age*, 7, pp. 11—17, July, 1920, pp. 13—23, August, 1920. *Technical Review*, 7, pp. 29—30, October 12th, 1920—Abstract. *Electrical World*, 76, p. 439, August 28th, 1920—Abstract.)

This article describes the high power station at New Brunswick which is equipped with Alexanderson alternators. Illustrations of the machine are given and of some accessories including a magnetic amplifier, and dimensions of the multiple antenna and of the counterpoise construction. Some particulars are included of the reduction in losses effected by the use of this type of antenna. The resonance voltage speed regulator is also briefly described.

1334. A New Wireless Transmitting Station at Geneva. (*Engineer*, 130, pp. 541—542, November 26th, 1920.)

Particulars of the installation of a high speed transmitting station for the use of the League of Nations meeting at Geneva, November, 1920. See also p. 2 in this issue.

1335. **R. H. Barfield.** Commercial Progress in Aircraft Wireless. (See pp. 4—14 in this issue.)

1336. **A. N. Goldsmith.** Radiotelephony across Oceans and Continents. (*Wireless Age*, 7, pp. 10—13, June, 1920.)

A general article dealing with the possibilities of long distance radiotelephony. A transmitting installation using 12 high-power valves at the College of the City of New York is briefly described and illustrated.

1337. **J. Usabiaga.** Wireless Telephony. (*Produccion*, 11, pp. 149—150, March 15th, 1920.)

1338. **C. G. Crawley.** Wireless Waves. (*Discovery*, 1, pp. 114—116, April, 1920.)

1339. Long Distance Speech by Wireless. (*Sea, Land and Air*, 3, pp. 466—470, October, 1920.)

A general descriptive article dealing with the advances in thermionic valve development.

1340. Powerful Wireless Station for Belgium. (*Engineer*, 130, p. 514, November 19th, 1920.)

A short note referring to the plans for a powerful transatlantic wireless station to be erected in Belgium. An average transmission rate of 60,000 words per day is to be provided for and the station is to employ 750—1,000 kW.

1341. American Radio Stations. (*Scientific American*, 123, p. 217, September 4th, 1920. *Wireless Age*, 7, p. 9, June, 1920.)

It is stated that the American Government shore radio stations now number 135, of which twenty are in Alaska, nineteen in the Philippines, three in the Canal Zone, two in Hawaii, and one each in Porto Rico, Guam and Samoa. The Government ship stations total 470.

1342. Wireless in the French Colonies. (*L'Électricité*, 2, p. 6, August 15th, 1920.)

A short note giving details of the progress effected in the French colonial wireless stations now under construction.

Spark Gaps and Spark Transmitting Apparatus.

1343. **P. R. Coursey.** Sparks and Spark Gaps. (*Wireless World*, 8, pp. 341—343, August 7th, 1920. *Technical Review*, 7, p. 68, October 19th, 1920—Abstract.)

1344. **T. W. Benson.** A Spark Coil Panel Transmitter. (*Wireless Age*, 7, pp. 24—25, May, 1920.)

An illustrated description and details for constructing the set.

1345. **L. R. Fielder.** A 60 Watt Low Power Transmitter. (*Wireless Age*, 7, pp. 29—30, May, 1920.)

1346. **W. A. Remy.** The Design and Construction of a Low Power Transmitter for Local Use. (*Wireless Age*, 7, pp. 30—32, May, 1920.)

1347. **L. S. Butler.** A Low Power Transmitter for Local Use. (*Wireless Age*, 7, pp. 32—33, May, 1920.)

1348. **J. E. Bethenod and E. Girardeau.** Producing Oscillations. (*French Patent* 502594, February 2nd, 1915. Published May 19th, 1920.)

In a method of producing electric oscillations the discharge of a main condenser is timed by the discharge of an auxiliary condenser connected in parallel with it through an adjustable inductance and resistance. The discharge circuit of the main condenser is coupled inductively to the discharge circuit of the auxiliary condenser, the latter containing a rotary spark gap driven from the shaft of the supply alternator. For further particulars see *British Patent* 100058.

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Arc Apparatus.

1349. **L. F. Fuller.** Improvements in Arc Generators. (*Wireless Age*, 7, p. 18, June, 1920. *Science Abstracts*, 23B, p. 398, Abstract No. 764, August 31st, 1920—Abstract. *Scientific American*, 123, p. 571, December 4th, 1920—Abstract.)

Abstract of a patent dealing with the design of magnet coils for arc oscillation generators. To avoid the necessity for providing a separate choke coil, the magnet windings are provided with extra heavily insulated turns on the outside and are connected in the positive lead instead of in the negative as is customary. The negative terminal of the dynamo as well as the dynamo frame may then be earthed.

1350. **G. M. MacKay.** An Improved Arc Generator. (*Wireless Age*, 7, p. 22, June, 1920. *Science Abstracts*, 23B, p. 548, Abstract No. 1041, November 30th, 1920—Abstract.)

In the apparatus described two fixed electrodes are employed in a partially exhausted enclosure containing hydrogen by preference. Means are provided for heating the cathode to start the arc. The heating current may be shut off when the arc is in operation.

Thermionic Valve Apparatus.

1351. **B. S. Gossling.** Development of Thermionic Valves for Naval Uses. (*Journal of the Institution of Electrical Engineers*, 58, pp. 670—703, August 19th, 1920. *Technical Review*, 6, p. 824, July 20th, 1920 Abstract. *Nature*, 105, p. 559, July 1st, 1920—Abstract. *Science Abstracts*, 23B, p. 581, Abstract No. 1112, December 30th, 1920—Abstract.)

See RADIO REVIEW, 1, pp. 544—545, August, 1920, for abstract. The discussion by C. L. Fortescue, C. C. Paterson, G. W. O. Howe, J. St. Vincent Pletts, J. Scott-Taggart, W. H. Eccles, and H. M. Dowsett is included in the original together with the author's reply.

1352. **W. H. Eccles.** Inaugural Address to the Wireless Section of the Institution of Electrical Engineers. (See pp. 31—37 in this issue.)

1353. Testing Marconi V.T.'s. (*Wireless Age*, 7, pp. 20—21, March, 1920.)

A summary is given of the tests through which the triode valves manufactured by the American Marconi Company are subjected. In addition to the electrical inspection they are also subjected to careful inspection for mechanical defects. In the electrical inspection the tubes are first tested for gas and classified as (1) soft tubes for detectors and oscillators, or (2) hard tubes for amplifiers and oscillators.

The following tests are made: Filament testing for current and voltage.; plate voltage; insulation resistance between plate grid and filament terminals after the tube has been in operation at normal current for some time; sensitiveness as a detector (checked against standard tube): oscillation tests at a wavelength of 250 metres using the plate voltage which gives maximum sensitiveness as a detector. Class 2 tubes are all subjected to a plate potential of 350 volts, their internal resistance and voltage amplification factors are also measured by means of a bridge arrangement. The article includes illustrations of the testing sets.

1354. **R. A. Heising.** The Audion Oscillator. (*Physical Review*, 16, pp. 216—237, September, 1920.)

This article deals almost entirely with the conditions that must be satisfied for the production of free oscillations in circuits attached to a three-electrode valve. A straight line characteristic is assumed. The bulk of the equations are derived for the "Hartley Circuit" in which the grid and plate circuits are coupled magnetically while at the end of the article the modifications necessary when a circuit of the Colpitts type is used are considered. No solution is given for the amplitude of the oscillation current set up but merely those for the circuit conditions necessary for the establishment of the oscillations. The paper is similar to another by the same author.*

1355. **F. K. Vreeland.** Improved Oscillator. (*Wireless Age*, 7, p. 26, September, 1920. *Science Abstracts*, 23B, pp. 549—550, Abstract No. 1044, November 30th, 1920—Abstract.)

In order to increase the purity of the oscillations set up by a triode valve it is proposed to employ a separate or "flywheel" circuit coupled to both grid and plate circuits of the valve by means of step-down transformers. In an alternative arrangement coupling may be electrostatic. Circuit diagrams of both arrangements are given.

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* RADIO REVIEW Abstract No. 1059, November, 1920.

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1356. **M. Latour.** Continuous Wave Transmitter. (*French Patent* 502633, November 11th, 1915. Published May 21st, 1920. *British Patent* 147462, July 7th, 1920. Convention date November 11th, 1915. Patent not yet accepted but open to inspection.)

The aerial is connected through a condenser, an inductance and a transformer primary to earth (Fig. 1). The plate of the thermionic oscillation generator is connected to the filament through a battery and the inductance in the aerial circuit and the transformer primary. The secondary of the transformer is connected across the grid of the generator and the filament.

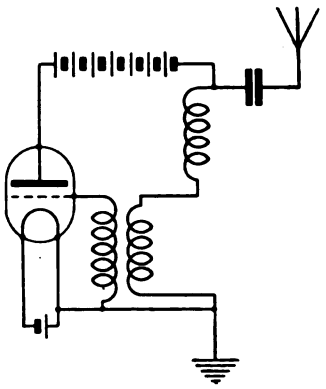

FIG. 1.

1357. A New Amplifying Relay. (*L'Électricien*, 51, p. 496, November 15th, 1920.)

The amplifying properties of the three-electrode valve are briefly described together with a mercury discharge apparatus possessing similar properties.

1358. **J. Bethenod.** Oscillation Generator. (*French Patent* 502519, November 5th, 1915. Published May 18th, 1920. *L'Électricien*, 51, p. 403, September 15th, 1920—Abstract.)

In an oscillation generator consisting of a vacuum tube having a cathode and two anodes, an alternating electric field produced by the action of the tube itself is used to oscillate the cathode beam from one anode to the other.*

1359. **M. R. Darmezin du Rousset.** Oscillation Generator. (*French Patent* 502512, October 28th, 1915. Published May 18th, 1920.)

The invention relates to tubes containing rarefied gases employed for the production or reception of electric oscillations. In the specific example described, the tube is of glass and contains, for example, rarefied neon, and at each end is an electrode mounted at the extremity of a copper or silver rod of large enough section to conduct the heat away rapidly. The electrodes are each connected to a radiation plate outside the tube, and the tube is supported in a magnetic field produced by two solenoids. The apparatus is placed in a cooling bath.

1360. **L. de Forest.** An Oscillating Current Generator. (*Wireless Age*, 7, pp. 17—18, June, 1920. *Technical Review*, 7, p. 357, December 14th, 1920—Abstract.)

The apparatus described consists of three bulbs exhausted to a low pressure and containing mercury vapour. A mercury arc discharge is set up between two of the bulbs which are connected to a suitable direct current supply. The third bulb contains an oil cooled plate electrode and a tubular grid electrode between the plate and the junction of the three bulbs. Oil cooling can also be provided for this grid electrode. The circuits used with the oscillation generator are somewhat similar to those often used with a triode valve, the arc discharge taking the place of the hot filament.

1361. **J. A. Fleming.** A Four-electrode Thermionic Detector for Damped or Undamped Electric Oscillations of High or Low Frequency. (See pp. 38—40 in this issue.)

Transmitter Control or Modulation.

1362. **L. F. Fuller.** Methods of Signalling with an Arc. (*Wireless Age*, 7, p. 25, September, 1920.)

In the arrangement described for signalling purposes one of the arc electrodes is attached to the core of a solenoid so that the arc is ignited or broken in accordance with the movement of the signalling key.

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* See also British Patent 126019—RADIO REVIEW Abstract No. 106, January, 1920.

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1363. **A. Taylor.** Continuous Wave Transmitter. (*French Patent* 502767, April 24th, 1919. Published May 26th, 1920.)

The specification describes methods of controlling the emission of waves for signalling purposes particularly applicable to arc and other C.W. systems.*

1364. **E. F. W. Alexanderson.** A Modulator for High Power Work. (*Wireless Age*, 7, pp. 23—24, September, 1920. *Science Abstracts*, 23B, p. 549, Abstract No. 1043, November 30th, 1920—Abstract.)

The arrangement described is a modification of the shunt control method in which a portion of the antenna energy is shunted off through modulating valves, the effective resistance of which is varied in accordance with the modulating currents. In this modification a number of special double-anode valves are joined in parallel and connected across the secondary winding of a transformer included in the circuit between the oscillation source and the antenna. By joining resistances in series with each of the anode circuits of each valve it is claimed that the amount of energy which can be controlled in this manner varies approximately as the square of the number of valves used in parallel.

1365. **M. Latour.** Magnetic Modulator. (*French Patent* 501473, December 16th, 1918. Published April 5th, 1920. *British Patent* 148949, July 10th, 1920. Convention date December 16th, 1918. Patent not yet accepted but open to inspection.)

The specification describes a magnetic modulator for insertion in a wireless aerial circuit and comprises an inductance having an iron core, the reactance of which is varied by mechanically modifying the air gap. The magnetic circuit is closed except for an air gap formed between poles separated by slots. Between the opposite poles is an armature formed of parts which are alternately conductors and non-conductors, the former acting as magnetic screens to decrease the reactance of the coil when they are in position between opposite poles.

1366. **Allgemeine Electricitäts-Gesellschaft.** Circuit for Wireless Telegraphy and Telephony. (*German Patent* 303393, July 10th, 1917. Patent granted September 27th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 304, October, 1920 – Abstract.)

A method of modulating the oscillations from a generator G by means of impressed voltage variations from a subsidiary circuit M, Fig. 2.

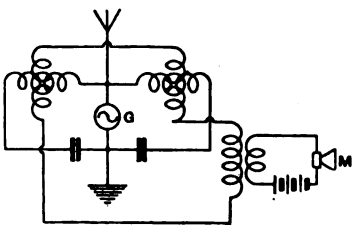

FIG. 2.

1367. **E. M. C. Tigerstedt.** Microphone. (*French Patent* 488251, January 2nd, 1918. Published September 17th, 1918.)

In the microphone described the terminals are formed by two parallel membranes between which is placed a ring of felt enclosing the necessary quantity of carbon granules; the two membranes, which are not enclosed, are mounted in but insulated from a ring provided with a handle in such manner that the microphone can be held so that it may be spoken to equally well on both sides. The rear membrane partially compensates for the violent vibrations of the front membrane.

Radio Receiving Apparatus.

1368. **R. E. Thompson.** Uni-control Receiver without a Coupled Tuned Circuit. (*Wireless Age*, 7, pp. 20—28, April, 1920.)

In the receiver described an aperiodic secondary is used and efforts are made to reduce its self-capacity as much as possible by using a spaced winding.

1369. **M. W. van Slyck.** A Modern Receiving Set. (*Wireless Age*, 7, pp. 27—28, May, 1920.)

The circuit described makes use of an elevated aerial connected to the primary circuit and an indoor loop aerial joined in series with the secondary. See also RADIO REVIEW Abstract No. 360, May, 1920.

* See also British Patent 135111—RADIO REVIEW Abstract No. 332, May, 1920.

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1370. **O. Scheller and C. Lorenz Aktiengesellschaft.** Receiving Arrangement for Wireless Telegraphy. (*German Patent* 299095, November 11th, 1914. Patent granted October 14th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 155, August 1920—Abstract.)

A receiving circuit in which primary or secondary reception may be utilised. The change from one type of working to the other is made by means of switch S (see Fig. 3).

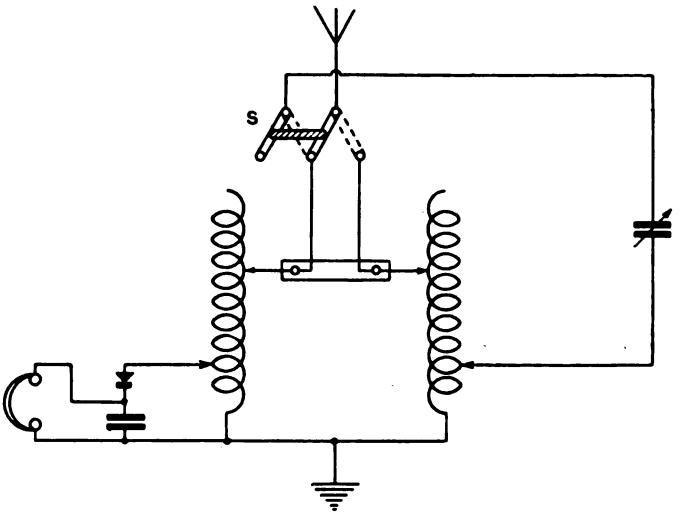

FIG. 3.

1371. **Gesellschaft für drahtlose Telegraphie.** Receiving Circuit for Wireless Telegraphy. (*German Patent* 307012, June 16th, 1915. Patent granted September 11th, 1919. Addition to German Patent 297907. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 150, August, 1920—Abstract.)

A primary or secondary receiver for portable wireless stations which may be used with the

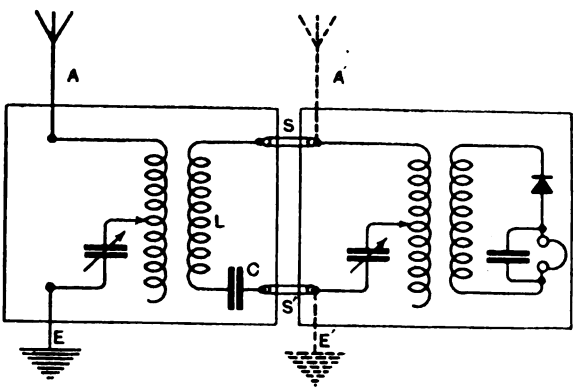

FIG. 4.

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antenna and earth connected either at A and E or at A′ and E′ (see Fig. 4). By a proper adjustment of the values of L and C and suitable manipulation of switches SS′ the tuning for the primary and secondary arrangements may be kept identical.

1372. **E. A. White.** An unusually simple Circuit for Long Waves. (*Wireless Age*, 7, p. 22, February, 1920.)

Two circuits are described for use with cascade amplifiers, in the first a variometer is employed for tuning the aerial, the grid filament circuit of the first valve being joined in shunt to it, while in the second a variable condenser is used in parallel with the aerial tuning inductance in shunt to which the grid filament circuit of the first valve is again connected; capacity reaction is employed. Tuning is thus reduced to practically only one operation.

1373. **O. Scheller and C. Lorenz.** Wireless Receiving Circuit. (*German Patent* 303804, January 30th, 1917. Patent granted October 30th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 156, August, 1920—Abstract.)

A receiver circuit consisting of a loop antenna inductance, and a capacity of which only the latter is variable. To provide high potential effects for the detector circuit a step-up transformer is used as link between antenna and detector circuits.

1374. **W. H. Kirwan.** Some Recent Amateur Apparatus. (*Wireless Age*, 7, pp. 38—40, March, 1920.)

Receivers covering a range of 200—20,000 metres are described.

1375. **E. F. Huth.** Wireless Receiving Circuit. (*German Patent* 310113, August 29th, 1917. Patent granted October 7th, 1918. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 296, October, 1920—Abstract.)

A circuit with two detectors so arranged that both halves of the wave are used. The rectified current effects are transferred to the receiving amplifier A by means of the transformers shown in Fig. 5.

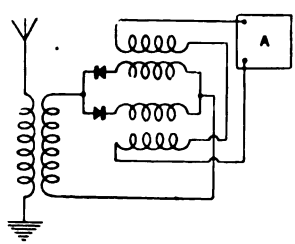

FIG. 5.

1376. **Deutsche Telephonwerke Gesellschaft.** Circuit for Wireless Receiving Station. (*German Patent* 315471, September 20th, 1916. Patent granted October 28th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 386, November, 1920—Abstract.)

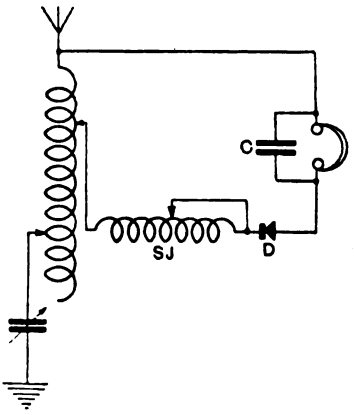

FIG. 6.

A circuit (see Fig. 6) in which a coil of variable inductance SJ is included in the detector circuit (contact detector D of high ohmic resistance). With the exception of the blocking condenser C across the telephone no further capacity is included in the detector circuit.

1377. **A. N. Goldsmith and E. T. Dickey.** Radio Taste Reception. (*Telegraph and Telephone Age*, 38, pp. 560 - 564, November 1st, 1920.)

Experiments are described to test the possibility of receiving radio signals on aircraft and other noisy places by means of the sense of taste. Successful results were obtained using two or more stages of amplification provided that the initial signal strength was of at least 500 times audibility.

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1378. **H. Hurm.** Crystal Detector. (*French Patent* 502760, March 21st, 1916. Published May 26th, 1920.)

The crystal detector has a number of contact wires with their inner ends bearing on the crystal and their outer ends connected to terminals which are engaged by a rotating arm, so that the point making the most sensitive contact is readily selected. The crystal is arranged to be rotated to vary the points of contact with the wires. For further particulars see *British Patent* 105905.

1379. **C. Florisson.** Rectification by Galena. (*Comptes Rendus*, 171, pp. 106—108, July 12th, 1920. *Revue Générale de l'Électricité*, 8, pp. 175—176, August 7th, 1920. *Science Abstracts*, 23A, p. 473, Abstract No. 1199, September 30th, 1920—Abstract. *Revue Scientifique*, 58, p. 444, July 24th, 1920—Abstract. *Electrical World*, 76, p. 840, October 23rd, 1920—Abstract. *Elektrotechnische Zeitschrift*, 41, p. 1040, December 23rd, 1920—Abstract.)

1380. **C. C. Henderson.** A Receiver-Transmitter. (*Wireless Age*, 7, p. 28, February, 1920.)

In the arrangement described the radiation from the receiving heterodyne is used for communication over short distances. Reference is also made to its use by the American Fleet during the war for inter-communication purposes.

1381. **M. Latour.** The Heterodyne Method of Wireless Reception, its Advantages, and its Future. (See pp. 15—21 in this issue.)

1382. **Compagnie Française pour l'Exploitation des Procédés Thomson-Houston.** Receiving Heterodyne Arrangement. (*French Patent* 500292, June 2nd, 1919. Published March 6th, 1920. *British Patent* 148131, July 9th, 1920. Convention date June 3rd, 1918. Patent not yet accepted but open to inspection.)

The grid current of a thermionic valve is arranged to vary inversely as the grid voltage over the operating range of negative grid potential. Such an oscillator is described as employed as a heterodyne receiver. The grid circuit of the valve consists of an inductance and a variable condenser in series, and a battery is arranged to give the grid a normal negative potential, the battery being connected through choke coils. The plate circuit includes a telephone shunted by a condenser.

1383. **M. Latour.** Receiving Arrangement. (*French Patent* 503047, October 21st, 1916. Published June 1st, 1920. *L'Électricien*, 51, p. 452, October 15th, 1920—Abstract. *British Patent* 148951, July 10th, 1920. Convention date October 27th, 1916. Patent not yet accepted but open to inspection.)

The signals are received by a cascaded amplifier and detected by a glow lamp by means of which they may be recorded photographically. For wireless telephony the photographic record is subsequently used in conjunction with a selenium cell for reproduction.

1384. **H. Abraham.** On Recent Progress in the Reception of Long Range Wireless Signals. (*Revue Générale de l'Électricité*, 7, p. 642, May 15th, 1920—Abstract.)

Abstract of an address delivered by M. Abraham to the Société Française des Électriciens on May 5th, 1920.*

1385. **J. Scott-Taggart.** A Vacuum Tube Trigger Relay. (*Wireless Age*, 7, p. 23, June, 1920. *Science Abstracts*, 23B, p. 494, Abstract No. 938, October 31st, 1920—Abstract.)

A description is given of the trigger relay arrangement due to W. H. Eccles and F. W. Jordan. See RADIO REVIEW, pp. 80—83, November, 1919, and pp. 143—146, December, 1919.

1386. **A. A. Campbell Swinton.** Wireless Telegraphy and Telephony. (*Wireless World*, 8, p. 639, December 11th, 1920. *Engineer*, 130, p. 503, November 19th, 1920. *Electrical Industries*, 20, p. 1466, November 17th, 1920.)

Notes relative to the first public demonstration of the application of the Creed telegraph apparatus to the reception of wireless signals. See also Wireless Telegraphic Printing on the Creed Automatic System. (Pp. 37—38 in this issue.)

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* See also RADIO REVIEW Abstract No. 826, September, 1920, for reference to the apparatus described.

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Subsidiary Radio Apparatus (including Protective Apparatus, etc.).

1387. **W. Rogowski.** High Voltage D.C. Machines for Supplying Spark Stations. (*Archiv für Elektrotechnik*, 9, pp. 191—226, September, 1920.)
An investigation of the danger of breakdown in such machines due to resonance and surges with special reference to the failure of two machines at Königswusterhausen. (See also pp. 22—25, in this issue, and next abstract reference.)

1388. **K. W. Wagner.** The Breakdown and Protection of High Voltage D.C. Machines Supplying Spark Transmitters. (*Elektrotechnische Zeitschrift*, 41, pp. 581—584, July 29th; and pp. 605—606, August 5th, 1920. *Electrical World*, 76, p. 647, September 25th, 1920—Abstract.)
See RADIO REVIEW, pp. 22—25, in this issue for Abstract.

1389. **Gesellschaft für drahtlose Telegraphie.** High Frequency Generator. (*German Patent* 303895, October 14th, 1917. Patent granted September 26th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 82—83, January, 1920—Abstract.)
A method of preventing the high frequency current of a continuous wave valve generator from reaching the direct current source by the insertion of an intermediary oscillating circuit tuned to the frequency of the generator.

1390. **F. Sarrart.** Advantages and Disadvantages of Various Systems of Transforming High Tension Alternating Current. (*Houille Blanche*, 19, pp. 101—106, May and June, 1920.)
A comparison of costs and efficiencies for various rectifier arrangements.

1391. **J. E. Lilienfeld and W. Hofmann.** Constant High Resistances for Measurement and Loading. (*Elektrotechnische Zeitschrift*, 41, pp. 870—873, November 4th, 1920.)
A new form of high resistance with the trade name "Multohm" consisting of a glass tube about 1 cm. diameter and 1 mm. thick with a carbon deposit on the interior. This deposit is made as a spiral to obtain very high values. Where greater constancy is required for measurement purposes a metallic oxide deposit is used instead of carbon. The allowable continuous loading is 1 watt per square centimetre of surface in air and three times this in oil. The application to radiotelegraphy is mentioned among other possible applications.

Aerials and Earthing Systems.

1392. **J. O. Mauborgne.** Resonance Wave Coils for Radio Transmission and Reception. (*Journal of the Franklin Institute*, 190, p. 743, November, 1920.)
A short note relative to a paper read before the Electrical Section of the Franklin Institute on October 14th, 1920. Various forms of resonance wave coils and their directive properties were described. Some consideration was also given to duplex and multiplex reception as well as to the use of these coils as wavemeters.

1393. **R. Villers.** Wireless Transmission of Energy. (*La Nature*, 48, pp. 292—294, May 29th, 1920.)
See RADIO REVIEW Abstract Nos. 701 and 702, August, 1920, where similar apparatus is described.

1394. Antenna Construction. (*Wireless Age*, 7, p. 23, January, 1920. *Science Abstracts*, 23B, p. 276, Abstract No. 543, May 31st, 1920—Abstract.)
Abstract of a patent by **M. Latour.***

1395. **L. T. Wilson.** A Coil Aerial. (*Wireless Age*, 7, pp. 18—20, April, 1920.)
A simple construction is described for a frame aerial for use as a direction finder.

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* See RADIO REVIEW Abstract No. 199, February, 1920, for reference and abstract. A drawing is also given of the construction of the loading inductance referred to in the patent and abstract.

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1396. **C. C. Pidgeon.** Indoor Antenna. (*Wireless Age*, 7, p. 28, June, 1920.)
An account is given of some experiments with a simple form of loop aerial.

1397. **A. Pfeiffer and W. Schmidt.** Apparatus for Wireless Telegraphy. (*German Patent* 317553, January 13th, 1918. Patent granted December 22nd, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 138, August, 1920—Abstract.)
Trains of high frequency oscillations of extremely large initial amplitude and very large decrement are detected by means of an antenna with electrode plates PP immersed in a good conducting medium (see Fig. 7).

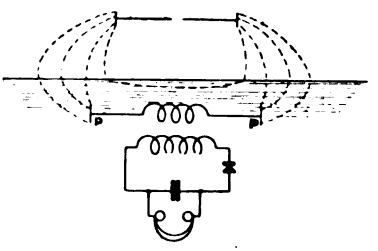

FIG. 7.

1398. **Gesellschaft für drahtlose Telegraphie.** Sending and Receiving Arrangement for Aircraft Wireless Telegraphy. (*German Patent* 317547, January 24th, 1918. Patent granted December 19th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 146, August, 1920—Abstract.)
The metal parts of the aeroplane are used as an antenna for very short waves. Electromagnetic coupling between the set and the antenna is used.

1399. **V. R. Fisher.** The Submarine Receiving Aerial. (*Wireless Age*, 7, pp. 26—27, March, 1920.)
The author criticises the claims made for the use of a loop aerial on submarines and mentions tests in which negative results were obtained. Some reference is also made to the frame aerial receiving arrangement used in France during the war for transatlantic reception.

1400. **C. R. Leutz.** A Portable Mast. (*Wireless Age*, 7, pp. 34—36, September, 1920.)
Constructional details are given and descriptions of the best method of erection.

Wave Transmission (Theory, Range Tests, Upper Atmosphere, etc.).

1401. **S. Chapman.** A Note on Magnetic Storms. (*Philosophical Magazine*, 40, pp. 665—669, November, 1920.)
A short note in reply to criticisms of an earlier paper by the same author relative to the impact of streams of corpuscles into the earth's atmosphere.

1402. **C. F. Brooks and H. Lyman.** The Auroræ of March 22nd—25th, 1920, and Associated Displays. (*Monthly Weather Review*, 48, pp. 379—392, July, 1920.)
A full description is given of the phenomena associated with this display, and of its geographical distribution together with some of its effects on radio signalling. No marked increase of atmospherics was noticed but signals received from Arlington showed enormous variation in strength with an irregular slow periodicity.

1403. **W. J. Humphries.** The Physics of the Aurora. (*Monthly Weather Review*, 48, pp. 392—393, July, 1920.)

1404. Distance of 7,500 Miles covered by 80 kW Station. (*Elektrotechnische Zeitschrift*, 41, p. 141, February 12th, 1920. *Electrical World*, 76, p. 199, July 24th, 1920—Abstract.)

Atmospherics.

1405. **M. I. Pupin and E. H. Armstrong.** A Negative Resistance for Atmospheric Reduction. (*U.S. Patent* 1334165, September 17th, 1915. Patent granted March 16th, 1920. *Wireless Age*, 8, pp. 22—24, October, 1920—Abstract.)
The specification describes a receiving system in the aerial circuit of which a resistance is introduced sufficiently high to screen the system from disturbances, while for the frequency which is to be received the effects of this resistance are wiped out by means of a valve with reaction operating as a negative resistance.

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1406. **Société Française Radio-Électrique.** Eliminating Atmospheric Disturbances. (*French Patent*, 502279, June 1st, 1915. Published May 8th, 1920. *British Patent* 147802, July 9th, 1920. Convention date June 1st, 1915. Patent not yet accepted but open to inspection.)

For the purpose of overcoming the effects of atmospherics, the receiving aerial is detuned and the signals are magnified by valve amplifiers with tuned circuits.

1407. **Marconi Wireless Telegraph Co. of America.** Eliminating Atmospheric Disturbances. (*French Patent* 502692, January 26th, 1918. Published May 22nd, 1920.)

To reduce or eliminate the effects of atmospheric disturbances a receiving system has two antennæ arranged at a distance of half a wavelength or less apart and in the direction of the signals to be received. Each antenna is formed of one or more coils, and a third coil is connected to the detector circuits and placed in the magnetic field of the coils connected to the antennæ in such a manner that the effects due to atmospherics operate differentially on the third coil, while the signal currents operate cumulatively on this coil.*

High Frequency Circuits (Theory, Components and Measurements).

1408. **E. H. Barton and Miss H. M. Browning.** Triple Pendulums with Mutual Inter-action and the Analogous Electrical Circuits. (*Philosophical Magazine*, 40, pp. 611—618, November, 1920.)

The theory of three mutually coupled electric circuits is given and a number of experiments with mechanically analogous pendulums are described. The article includes some reproductions of the traces from the pendulums.

1409. **E. Bellini.** Oscillation Generator. (*French Patent* 502719, February 2nd, 1916. Published May 25th, 1920. *L'Électricien*, 51, p. 429, October 1st, 1920—Abstract. *Annales des Postes, Telegraphes et Telephones*, 9, p. 482, September, 1920—Abstract.)

Two oscillatory circuits are coupled so as to produce oscillations having a single frequency by a combined magnetic and electric coupling, each having the same coupling coefficient.†

1410. **Compagnie Française pour l'Exploitation des Procédés Thomson-Houston.** Receiving Apparatus. (*French Patent* 500720, June 14th, 1919. Published March 23rd, 1920. *British Patent* 147811, July 9th, 1920. Convention date June 15th, 1918. Patent not yet accepted but open to inspection.)

The specification describes means for adjusting the resonance frequency of receiving coils for wireless signalling. In one example, the coil is formed in three portions connected in series and arranged radially round a common centre about which they may be turned so as to vary the distributed capacity and inductance. In another example, the coil sections are arranged co-axially and alternate sections are moved parallel to the other sections. By using a common operating bar, two such coils may be adjusted simultaneously. In a receiving circuit described and illustrated the receiving coil is connected across the grid and filament of a valve amplifier and the plate circuit is connected by a transformer to the grid circuit of a second valve whose plate circuit is connected to a telephone receiver. The secondary of the inter-valve transformer is formed similarly to the receiving coil.

1411. **F. V. Braemer.** Multilayer Inductance for Long Wave Work. (*Wireless Age*, 7, pp. 26—27, May, 1920.)

Multilayer pancake type coils of approximately rectangular cross section are described. Apparently no special precautions are taken for reducing self-capacity other than the insertion of a layer of paper between each layer of wire.

1412. **G. C. Southworth.** Electrical Measurements at Ultra-radio Frequencies. (See pp. 25—31 in this issue.)

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* See *British Patent* 132548—RADIO REVIEW Abstract No. 312, April, 1920.

† See also *British Patent* 126978—RADIO REVIEW Abstract No. 22, November, 1919.

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1413. **O. C. Roos.** Universal, Honeycomb and Lattice Coils in General. (*Wireless Age*, 7, pp. 22—24, July, 1920; pp. 23—26, August, 1920; pp. 12—19, October, 1920; pp. 14—16, November, 1920; pp. 16—17, December, 1920.)

This article gives an exhaustive *résumé* of the different types of winding available for honeycomb types of multilayer lattice coils. The distinctions between the different types of windings are given together with winding details of different kinds of coils and an approximate theory of the best methods of winding. A large number of formulæ are also deduced for use in the design for these coils.

1414. **W. Gereach.** The Calibration of Thermo-junctions as A.C. Ammeters. (*Physikalische Zeitschrift*, 21, pp. 550—551, October 15th, 1920.)

The junction forms one arm of a bridge of which the others are resistances. The source is a battery with a reversing switch and adjustable resistance. The galvanometer of the bridge will show a steady deflection due to the thermal E.M.F., but when the resistances are balanced, this will not change on reversing the current. The galvanometer deflection is then a measure of the thermal E.M.F. The arm in series with the junction contains an ammeter to determine the current through the junction.

1415. **H. Abraham, E. Bloch and L. Bloch.** Amplifying Voltmeter. (*Bulletin de la Société Française des Électriciens*, 10, pp. 9—24, January, 1920. *Electrical World*, 76, p. 249, July 31st, 1920 Abstract. *Technical Review*, 6, p. 622, July 20th, 1920 Abstract.)

To read small voltages, they are amplified by means of triodes, then rectified and read on a moving coil instrument in the plate circuit. The pointer of this instrument is normally adjusted to zero by a potentiometer device. As many as five stages of amplification have been used. The set which was worked out in 1918 was constructed by Carpentier for the French military authorities. Details of the calibration of the instrument and a number of examples of its application are given.

High Frequency Wire Telegraphy and Telephony.

1416. **K. W. Wagner.** Multiplex Telephony and Telegraphy using High Frequency Currents (Wired-Wireless). (*Elektrotechnische Zeitschrift*, 41, pp. 706—710, September 9th, 1920. *Technical Review*, 7, p. 222, November 16th, 1920—Abstract. *Electrical World*, 76, p. 985, November 13th, 1920—Abstract.)

See RADIO REVIEW, 1, pp. 715—716, November, 1920, for abstract.

1417. **G. Arco.** High Frequency Telephony on Overhead Power Transmission Lines. *Elektrotechnische Zeitschrift*, 41, pp. 785—788, October 7th, 1920. *Technical Review*, 7, p. 392, December 21st, 1920—Abstract.)

Paper read at the annual congress of the Verband Deutscher Elektrotechniker at Hanover. It gives a more detailed and illustrated description of the system than in a previous article in the *Elektrotechnische Zeitschrift*.* Diagrams are given showing duplex working and intercommunication with the ordinary telephone system.

Traffic Particulars (Transmission Programmes, etc.).

1418. The New Meteorological Service from the Eiffel Tower. (*La T.S.F. Moderne*, 1, pp. 258—261, November, 1920. *La Nature*, 48 (2), Supplement p. 153, November 13th, 1920.)

Details are given of the revised programmes which came into force on November 1st, 1920.

1419. **P. Corret.** Transmission Programmes. (*La T.S.F. Moderne*, 1, pp. 275—279, November, 1920.)

1420. The Work of the German Wireless Stations. (*Elektrotechnische Zeitschrift*, 41, p. 593, July 29th, 1920.)

A brief note of the sending programmes of Norddeich and Königswusterhausen.

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* See RADIO REVIEW Abstract No. 1325, December, 1920.

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1421. America and France Linked by Wireless Telephony. (*Wireless Age*, 7, p. 7, March, 1920.)
Reference is made to a test between the New Brunswick Station and France.

1422. Commercial Radio across Atlantic and Pacific. (*Wireless Age*, 7, p. 10, March, 1920.)
Reference is made to the reopening of high power stations in America after their release by the U.S. Government on February 29th. The text of a number of congratulatory messages is given.

2. Books.

THE HOW AND WHY OF RADIO APPARATUS. By H. W. Secor. (New York: *Experimenter Publishing Co., Inc.* 1920. Pp. 160. Price $1.75.)

This volume which is written mainly for the radio experimenter and practical man is built up of a series of articles, treating of different parts of radio equipment, that have been published in American journals—particularly in the *Electrical Experimenter*. In his preface the author states that he hopes also that the book will be of use to the commercial radio operator both to give him an insight into the working of his gear, and also to enable him to reconstruct or replace parts that may be damaged by an accident or breakdown. With this object in view the chapters have on the whole been well chosen, while the introductory material dealing with elementary electricity and magnetism that usually encumbers most books of this class has been omitted. Mathematical working has also been kept out except in the three final chapters which treat of the subject of the calculation and measurement of inductances and the main features of their design for specific purposes—such as receiving tuners. A number of formulæ are given together with graphical charts to aid calculation, and it is noteworthy that the author does not attempt to give *every* possible formula for calculating inductance but merely a judicious selection, although it is possible that even some further slight simplification might have been made here with advantage.

P. R. C.

THE CONSOLIDATED RADIO CALL BOOK. (New York: *The Consolidated Call Book Company, Inc.* Second Edition, July, 1920. Pp. 160. Price $1.25.)

This book is correctly described by its sub-title "The Telephone Directory of the Sea." It contains the call letters and wavelengths of stations of all nations, together with the necessary information regarding the rates charged, etc. Particulars are given of radio compass stations, time signals, press schedules, weather reports, high power radio stations of the world, etc. A section is devoted to the call signals of American amateurs. The book contains much information useful to the wireless operator whether professional or amateur.

G. W. O. H.

New Books.

Announcements have been made of the early publication of two new volumes of interest to radio engineers—(1) "Wireless Design and Practice," by M. B. Sleeper, which is to be published by Messrs. Frowde, Hodder and Stoughton; and (2) "Wireless Telegraphy and Telephony," by L. B. Turner, M.A., which is to be published by the Cambridge University Press.

We hope to publish reviews of these books in a later issue.

Books Received.

THE WIRELESS EXPERIMENTER'S MANUAL, INCORPORATING HOW TO CONDUCT A RADIO CLUB. By Elmer E. Bucher. (New York: *Wireless Press, Inc.* 1920. Pp. 335. Price 12*s.* 6*d.* net.)

REPORT OF THE CHIEF SIGNAL OFFICER OF THE U.S. ARMY TO THE SECRETARY OF WAR, U.S.A., 1920. (Washington: *Government Printing Office.* 1920. Pp. 64).

REPORT OF THE DIRECTOR OF THE AIR SERVICE TO THE SECRETARY OF WAR, U.S.A. (Washington: *Government Printing Office.* 1920. Pp. 49.)

WIRELESS APPARATUS FOR RECEPTION. List W. 2. (London: *H. W. Sullivan.* Pp. 47. Price 1*s.*)

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Correspondence.

THE R.A.F. DIRECTION FINDING SYSTEM.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In the November issue of the RADIO REVIEW there appears an article offering various criticisms of the method generally known by the above name, in which some of the remarks are strongly open to question.

I do not propose to deal with the question of whether this is a new system in principle or not; but during the last nine months I have been conducting a close investigation into the working of the above system, and my results in some cases differ very much from those suggested by Major Prince. The results will shortly appear at length in the RADIO REVIEW, but as the paper was completed before this article appeared, no special attention has been drawn in it to these points. The chief ones are as follows :—

(1) In the middle of p. 697 Major Prince states that the change of angle necessary in this system is the same as for the primitive loop. My results show that in many cases the change in this system is not more than 40 per cent. of that required for the primitive loop, and this figure could probably be improved on, as no effort was made to determine its minimum value.

(2) The 90° ambiguity (p. 697). This I have also shown in some detail is a very good point on paper, especially when the two coils are supposed equal, but such a ratio is never likely to be used in the R.A.F. system ; and with the ordinary ratios if an attempt were made to determine this 90° bearing, equality of signal strength would be found to persist over an arc of 60° to 70°. No sane observer would mistake this for the real bearing.

(3) The argument (p. 698, line 7) and the reference (p. 696, line 12) as to the shapes of the curves. It is well known to anybody who has done much direction-finding work that the critical test is not the appearance of diagrams based on a formula which neglects small errors, but the behaviour in actual working. With an actual coil it is nearly always found that the zeros are neither total nor 180° apart, due to small subsidiary E.M.F.'s which are neglected in the simple cosine rule. In the R.A.F. system the effect of these (especially the first) is much less than with the primitive loop.

(4) The effect of increasing the number of turns (p. 699) has now been shown mathematically to be not more than a few parts in 10,000 with coils of normal size.

(5) There is one other point worth reference, namely the implication that, because by using a ratio of coil size somewhat less than unity, the results in the R.A.F. system are improved, therefore, the best results are obtained whether this is carried to the limit, when the system becomes the old single coil.

The results given above as to perception of least signal change disprove this, but an even greater factor is introduced by the errors. The problem of the blunt minimum on the single coil is a very old one, and has often been met by compensating devices. In the R.A.F. system by proper choice of the ratio it is possible, as shown above, to reduce enormously the effect of those errors without the use of such devices and without sacrificing the advantages of the reduced audible change.

For the sake of brevity I have only touched lightly on the main points, but there are several others of less importance which are equally open to question.

J. HOLLINGWORTH.

College of Technology, Manchester.
December 3rd, 1920.

Binding Cases and Index for Volume I.

Binding cases for Volume I. of the RADIO REVIEW will be issued shortly, together with the index. An announcement giving full particulars with regard to these will be published in our next issue.

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THE RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

VOL. II **FEBRUARY, 1921** NO. 2

Editor:
PROFESSOR G. W. O. HOWE, D.Sc., M.I.E.E.
Assistant Editor:
PHILIP R. COURSEY, B.Sc., A.M.I.E.E.

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INFORMATION FOR CONTRIBUTORS

All correspondence relating to contributions should be addressed to The Editor, The "Radio Review," 12 & 13, Henrietta St., Strand, London, W.C. 2.

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THE
RADIO REVIEW

VOL. II FEBRUARY, 1921 NO. 2

Editorial.

We publish in this number the first instalment of an interesting paper by Professor Vallauri of Leghorn who has done much experimental work on the measurement of the strength of the electromagnetic field produced by a transmitting aerial. We recently described his measurements of the strength of the field produced in Italy by the transmitting station at Annapolis. The present article deals with measurements at distances of two or three wave-lengths, that is before the effects of absorption, reflection or refraction become appreciable. Such measurements serve to determine the effective height of the transmitting aerial considered as the upper half of an ideal Hertzian oscillator or dipole, but they require to be carried out with extreme care if trustworthy results are to be obtained. Professor Vallauri's results appear to leave nothing to be desired in this respect. In his discussion of the factors affecting the effective height he draws attention to the effect of the parasitic currents in masts, guys, etc., an important matter often overlooked.

Hertz—the Unit of Frequency.—In an article in the *Elektrotechnische Zeitschrift* of July 29th, 1920, K. W. Wagner of the Physikalisch-Technischen Reichsanstalt suggests that in honour of the great physicist Heinrich Hertz, his name be given to the unit of frequency, viz., one cycle per second. Wagner proceeds to act on his own suggestion by using the term throughout his article, and the ordinary alternating current power supply is referred to as having a frequency of 50 Hertz. If the usual custom were followed this would become in English 50 hertz, the capital being dropped when the word is used as the name of a unit and not as the name of a man. We cannot but feel, however, that the name of Hertz is more suggestive of a frequency of a million cycles per second than of one cycle per second.

A Persistent Fallacy.—When an electromagnetic wave is propagated over the surface of the earth as in radiotelegraphy, the horizontal magnetic field and the vertical electric field are related in such a way that, if at any moment the magnetic field at a given point has its maximum value, the electric field at the same point has its maximum value at the same moment. A quarter of a period later the magnetic field strength will pass through zero, and the electric field strength at the same point will pass through zero at the same moment. At this latter moment the displacement current at the point, which is proportional to the rate at which the electric field strength is changing, has of course its maximum value.

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In a paper read before the British Association in 1913 we drew attention to this fact, and pointed out that some of the earlier text books on the subject had unfortunately contained very explicit descriptions and diagrams based on the assumption that the electric and magnetic fields occurred alternately at a given point and not simultaneously. This wrong idea seems to have taken root and to be very difficult to eradicate. On page 160 of Vol. I. of Stanley's Text Book of Wireless Telegraphy is a diagram which represents the fields quite correctly, but then the author proceeds as follows: "Imagine that we could see the strains in the ether as colours, that an electric strain acting downwards is represented by red, one acting upwards by blue, a magnetic strain in one direction by yellow and in the opposite direction by green. Then a person standing in the ether would see a red colour of electric strain which will grow in intensity and then die out giving place to a yellowish colour of magnetic strain which grows in intensity as the red dies out. As the yellow fades away it will give place to a blue colour of electric strain; this deepens and then fades away giving place to a green magnetic one. As the green one fades away the red will come on again and the whole cycle will be repeated."

It is regrettable that such a beautiful colour scheme should be employed to impress such false conceptions upon the mind of the reader.

Wireless Telephony in Forestry.—We notice that at the congress recently held at Vancouver in connection with the logging industry it was reported that wireless telephone installations had been erected during the summer at a number of land stations and on a number of launches used by the forest rangers. Although some interference had been experienced both from large wireless stations and from street car services in the neighbourhood of Vancouver, the telephone sets had proved very useful especially in giving early reports of forest fires. The programme for 1921 contains a considerable addition to the number of these stations.

The Range of Wireless Stations.—On December 15th Captain Trench read a paper on "The Range of Wireless Stations" before the Wireless Section of the Institution of Electrical Engineers. The most interesting feature of the paper was the list of suggested empirical factors to be introduced into the Austin-Cohen transmission formula in order to allow for all the various conditions likely to be met with in practice, *e.g.*, mountains, bad earths, etc. In the proof of the paper an error entered into many of the formulæ owing to the author introducing the correction for the distributed capacity twice, once as a reduction of effective height and once as a reduction from mean aerial current to current at base; these are of course alternative methods and should not both be employed. In seeking for an explanation of the smallness of the received current compared with that calculated from the dipole formula, the author puts forward the suggestion that the receiving aerial drains the ether in its neighbourhood in such a way that the E.M.F. induced in the aerial is less than that given by the usual formulæ. This

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suggestion contains a certain amount of fact; the receiving aerial does modify the electromagnetic field by superimposing upon it its own radiated field. This is allowed for, however, by adding to the actual resistance of the receiving aerial a fictitious resistance, which causes the received current to be smaller than would be calculated without this fictitious resistance.

The real explanation of the apparent smallness of the received current is to be found in the excessive values often assumed for the effective heights of aerials. Every mast and stay has a current induced in it, which is in opposition to that in the aerial and which has the same effect as a reduction of effective height. Austin's results over short distances are in perfect agreement with theory if the aerials be assumed to have an effective height of a little more than half the total height above water level.

A point which is often overlooked in discussing radiation and radiation resistance is the large amount of power radiated by the long horizontal part of a bent aerial and which contributes but little directly to the useful radiation power because of the direction of the oscillator. T aerials should be superior to Γ aerials in this respect the currents in the two halves of the roof tending to neutralise the effect of each other. They should also be superior with respect to earth losses, either with a direct earth or with a counterpoise.

The Lafayette Radio Station.—On December 18th, 1920, Admiral Magruder on behalf of the American Ambassador handed over to the French Government the high-power wireless station erected during the war at Croix d'Hins. This station which is known as the Lafayette station was built by the United States Navy in co-operation with the French military radiotelegraphic authorities. On p. 85 in this issue we give a description of some of the details of this station together with some interesting particulars of the preliminary tests that were carried out with it.

This station is intended to work with the New Brunswick station in the United States, and as a result of an agreement arrived at between the French Government, the Compagnie Générale de Télégraphie sans Fil and the Radio Corporation of America this station will handle traffic with the United States between the following hours: 0900 to 1200 and 1700 to 1900, G.M.T. The normal wavelength of transmission is about 23,400 metres.

It may be of interest also to note that this same agreement arranges for additional traffic to be handled from Lyons station on a wavelength of 15,000 metres between the following times:—0100 to 0300, 0500 to 0700, 1300 to 1500, and 2100 to 2400, G.M.T. **[1976]**

A New Slide Rule.—On December 10th, 1920, Mr. J. St. Vincent Pletts read a paper before the Physical Society of London describing a new slide rule of his invention, which possesses some advantages over the ordinary patterns customarily employed, in that the rule is made easier of operation for the calculation of the more complicated mathematical functions. The same rule was exhibited at the Physical Society Exhibition in January, and will be described briefly in connection therewith in our next issue.

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The Effect of the Heaviside Layer on the Apparent Direction of Electromagnetic Waves.*

By T. L. ECKERSLEY, B.A., B.Sc.

Numerous attempts have been made from time to time to explain the vagaries of long distance wireless telegraphy as the results of the action of a conducting layer of the upper atmosphere.

In particular the theories of Fleming and Eccles are on these lines and invoke the aid of what is generally known as the "Heaviside conducting layer" which is supposed to exist at the height of 50 to 100 km above the surface of the earth. Although we know very little as yet of the nature and constitution of this conducting layer there seems very little doubt as to its existence.

Schuster has shown (*Phil. Trans. Royal Soc.*, Vol. 208A, p. 182 (1907)) that the diurnal variation of the magnetic elements at the surface of the earth can be accounted for by the currents produced by the tidal motion of such a layer in the earth's permanent magnetic field. The presence of ultra-violet rays in the sun's radiation will ionise the air and make it conducting, and Swann has calculated that this conductivity will increase very rapidly with the height above the earth's surface; direct experiments on the number of ions produced at great heights on mountains, etc., confirm these calculations.

In this paper an account is given of phenomena which afford striking additional evidence of the existence of this conducting layer, and which give an insight into some of the processes which go on in this region of the upper atmosphere.

The development of "direction finding" by wireless has put a powerful instrument in the hands of the investigator, and it is with material derived from this source that the paper deals.

In its simplest form the electrical direction finder is just a closed loop of wire which can be rotated about a vertical axis, and which is coupled to some wireless receiving device. If this loop is tuned to receive wireless waves from any transmitting station then when the plane of the loop is perpendicular to the line joining it to the transmitter no signals will be received. The reason for this is that in a plane wave the magnetic force is everywhere perpendicular to the direction of propagation, and there is therefore no flux linked with the loop in this position, and no E.M.F. induced.

The property of closed loops can be utilised to find the directions of transmitting stations, and the method is the simplest of all that have been devised for so doing.

The rotating loop, which, for mechanical reasons, is limited in size, is consequently insensitive, and the more sensitive "Bellini-Tosi" system has therefore been devised.

* Received May 14th, 1920, and in final form, December 3rd, 1920.

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This consists of two large closed aerials in perpendicular vertical planes which are connected to the two fixed coils of an instrument called the goniometer. This instrument has two coils fixed in perpendicular planes each connected to one of the two large aerials. A third smaller coil which can turn about an axis which is the intersection of the central planes of the two fixed coils is connected to the receiving instrument.

The currents induced in the two aerials by the incoming waves are in phase and produce a resultant magnetic field R, the direction of which depends on the relative strengths of the currents in the two aerials, *i.e.*, upon the direction of the ray from the transmitter to the receiver. When the plane of the movable (or search) coil is perpendicular to this ray no signals will be received. The determination of this null point therefore gives the direction of R, and it is easy to show that this can be arranged to read off directly the direction of the transmitter.

All operators who have worked with this instrument agree that bearings taken in the daytime, that is, from about one hour after sunrise to one hour before sunset, are very fairly consistent, and that the probable error of a single bearing is about $\frac{1}{2}°$ in the most favourable circumstances, varying to 1·5° to 2° in less favourable cases.

These day bearings are liable to systematic errors which in certain cases may be considerably greater than 2°, due, for example, to refraction of the ray at a coast line, but the accidental errors appear to be chiefly, if not entirely, errors of observations. For instance the probable error of a station which gives weak signals is much greater than that of a station which gives strong signals, for the difficulty of measurement is very much greater in the former case.

When a large number of bearings are taken on a fixed station the probable error of the mean may be less than $\frac{1}{10}°$, and the plotted bearing often passes within this limit of the true bearing. These figures will give an idea of the accuracy which can be obtained in the daytime. On the other hand bearings taken at night may be quite unreliable. They are subject to large fluctuations and variations, and it is very often impossible to get a well defined minimum at all, so that the bearings are indefinite.

The liability to fluctuation appears to be greater in southern latitudes (*e.g.*, Cairo and Salonika) than in northern latitudes (*e.g.*, England and France). They are particularly liable to occur when the ray from transmitter to receiver passes over mountainous country; when the ray passes over the sea or open country the bearings are comparatively free from these fluctuations. They only occur when the transmitter is more than about twenty miles from the receiver, and they appear to reach a maximum when the stations are separated by about 300 to 400 miles of land. In northern latitudes the variations appear to be most marked at about sunset, or a little later, but further south the fluctuations continue throughout the night with unabated vigour. They occur on all wavelengths from 300 to 5,000 metres and upwards, and they do not appear to be specially marked on any wavelength in this range.

The following examples give an idea of the variations of the night bearings.

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The first is an example in which there appears to be very little systematic error (*i.e.*, the errors are as much positive as negative).

The transmitting station at Damascus was situated about 400 miles from the receiver at Cairo. The intervening country is partly hilly, partly dry desert sand and partly well irrigated alluvial country. It was a high power station working regularly on a 2,600 metre wavelength. The bearings fluctuate over a large range in the course of a few minutes, and deviations from the mean as great as 25° have been observed. The attached curve (Fig. 1) illustrates the results. The true bearing is 50·5° and the mean of the night bearings is 49·5°. The standard deviation from the mean is 12° which is large compared with the standard deviation of the day bearings (about 0·5°).

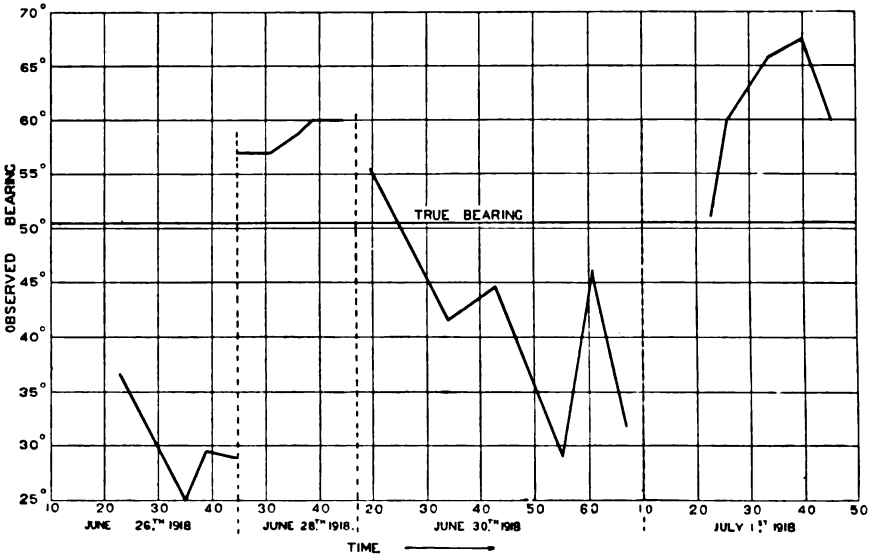

FIG. 1.—Variation of Night Bearings taken on Damascus.

The second is an example of a station which gives a well marked systematic error at night. The transmitting station was situated at Jamboli about 300 miles from the receiving station, which was at Salonika, and the intervening country was very mountainous, the ranges reaching a height of 7,000 or 8,000 feet in some places. The true bearing of the station was 55°. The mean of twenty-three night bearings was 73°, and the probable error of this mean (estimated in the usual way) was 1·25°. The systematic error 18° (73° — 55°) was therefore fifteen times the probable error of the mean and more than three times the probable error of a single observation. As far as the observations went there appeared to be no tendency for the systematic error to vary over ranges greater than its probable error.

The following example is interesting as the bearings show a marked con-

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trast in behaviour at two receiving stations a considerable distance apart. The transmitting station (at Sofia) was situated in very mountainous country. The receiving station (1) at Salonika was about 100 miles away and No. 2 at Cairo was about 800 miles away. The bearings at station (1) were so indefinite at night that it was practically impossible to get any results at all (the day bearings were quite accurate). At station (2) bearings at night were all fairly consistent, errors seldom exceeding 2° or 3°. Similar errors were obtained at night when the waves passed over fifty or sixty miles of desert in the Northern Sinai Peninsula.

Instances of this kind might be multiplied almost indefinitely, but enough has been said to give a good idea of the nature of the fluctuations.

It is not difficult to find an explanation which, in the present state of our knowledge, is sufficient to account for these results. The theory is that these results are due to rays reflected or refracted at some upper conducting layer of the atmosphere, and it will be proved later that this theory is at least an approximation towards the truth.

In a very crude form the theory put forward is the following. The essential fact to be explained is that the loop can receive signals from a transmitting station even when the plane of the loop is perpendicular to the line joining the two stations, *i.e.*, the ray from the transmitting to the receiving station. Now it can be shown that if an electric wave passes over the surface of separation of two media (one of them being conducting) in a direction parallel to the surface, the magnetic force in the wave front must be parallel to the surface of separation and perpendicular to the direction of propagation so that it can produce no E.M.F. in the loop so long as the plane of this is perpendicular to the normal to the wave front (*i.e.*, the ray). We may therefore infer from the presence of an E.M.F. induced in the loop the presence of some other ray from the transmitting to the receiving station reflected or refracted in either a horizontal or a vertical plane, or both.

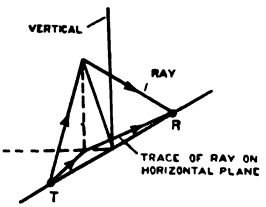

FIG. 2.

The theory put forward is that the effects observed are chiefly, if not entirely, due to the ray reflected in the *vertical plane*. It may be well to emphasise the fact that the observed deviations of bearings do not necessarily imply that the ray from transmitter to receiver is tilted to one side or the other (see Fig. 2). It will be shown later that a ray, which remains entirely in the vertical plane passing through the transmitter and receiver, is capable of producing the effects observed.

Of course neighbouring mountain masses will reflect the waves in a horizontal plane to a certain extent, and the passage of the waves over earth of varying conductivity will subject them to a sort of refraction in a horizontal plane (indeed there is direct experimental evidence of this), but there are many reasons why this sort of reflection or refraction cannot account for the fluctuations observed at night. In the first place it cannot account for the difference between the day and night bearings, and the rapid variations of

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the latter are unexplained. Again a mass of mountains will reflect at least as much energy from a station situated a few miles away from it as from a distant station. But it is only the bearings of comparatively distant stations ($d >$ twenty miles) which are subject to error, which cannot therefore be due to this cause, *i.e.* reflection in a horizontal plane. These facts alone would be sufficient to dispose of the hypothesis without taking into account the fact that the errors are observed in flat countries where considerable reflection in a horizontal plane is impossible.

To return to the former theory, the existence of a ray reflected in a vertical plane presumes the presence of some more or less well defined reflecting layer in the atmosphere; such a layer might, for instance, be due to a sudden change of density or to the presence of free ions or electrons. The change of density seems quite insufficient to produce any marked reflection, so we are driven to consider the effect of a conducting layer due to the presence of free ions or electrons. If the lower surface of this layer is fairly well defined there will be a considerable amount of reflection, but if the change of conductivity is sufficiently gradual the amount reflected will be small.

This brings us to the second essential fact to be explained, that is the existence of the fluctuations by night but not by day. This would be explained if the lower surface of the conducting layer were sharply defined at night but ill-defined in the daytime. Now this is roughly what we might reasonably expect; for the ionisation of the atmosphere is largely due to the action of the ultra-violet rays of the sun, so that in the daytime the lower regions of the atmosphere will be penetrated by the rays and become ionised. On account of the absorption of these rays there will be a gradual decrease of ionising power as the rays approach the surface of the earth, so that we should be led to expect an increase of conductivity up to some limiting height where the pressure is so low that there are insufficient molecules to provide ions to produce any conductivity. Now the conductivity depends upon the number of ions N and the velocity of these ions under unit electric force (which is nearly inversely proportional to the pressure). According to the theory of Swann, N, the number of free ions, is nearly constant over a considerable range at great height, and the increase of conductivity with the height is due to the decrease of pressure which is accompanied by a corresponding increase of the velocity of the ions under unit electric force.

Where N is approximately constant the rate of re-combination of the ions will be nearly proportional to the re-combination coefficient α, $\left(\frac{\partial N}{\partial t} = -\alpha N^2\right)$ which, in its turn, is nearly proportional to the pressure, so that at great heights where the pressure is low the rate of re-combination may be so small during the night that the number which re-combine during this period may be neglected; at lesser heights the rate of re-combination, which is proportional to the pressure, will be greater, and the ionisation will rapidly disappear after the removal of the ionising agent, *i.e.*, the ultra-violet rays of the sun. This process results in the existence of a more or less permanent layer at

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great heights accompanied by a state of ionisation varying with the light intensity at lower levels.

Now if the curve (1) in Fig. 3 represents the variation of conductivity with the height during the daytime curves (2), (3) and (4) will represent the same variation at increasing intervals after sunset. Now it is obvious that whatever the form of curve (1) (so long as σ increases gradually with h) the curves (2), (3) and (4), etc., show a much more abrupt transition from the non-conducting to the conducting layer of the atmosphere than the curve (1), and the lower edge of the layer is therefore much more sharply defined at night.

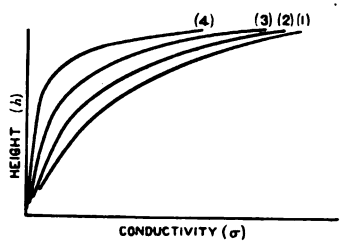

FIG. 3.

We should therefore expect a large amount of reflected energy at night and only little, if any, in the daytime.

Hence, this hypothesis will explain the difference between the effects observed at night and those observed during the daytime. This rather crude expression of the theory requires a critical mathematical treatment before it can be accepted with a degree of confidence. It must be shown that it can account for the facts quantitatively as well as qualitatively.

Before attempting this I will describe experiments which prove :—

(1) That there is a ray reflected in a vertical plane at night and not by day.

(2) That the magnitude of the error in bearing (fluctuation) varies in proportion to the strength of the ray.

(3) That the intensity of the ray is of the right order of magnitude to produce the effects observed.

As a preliminary the conditions under which an E.M.F. can be induced in a frame situated on the surface of the earth with its plane perpendicular to the direction of the transmitting station, will be investigated.

Now, so long as the magnetic force is in the plane of the loop the total E.M.F. induced in it will be zero. We have therefore to examine under what conditions there can be a magnetic force in the direction of the ray. We will assume at the outset that the distance between the transmitting and receiving stations is so short that the curvature of the earth in the interval may be neglected ; on the other hand we will also assume that the stations are so far apart that the waves at the receiving station are approximately plane. Under these conditions the problem assumes a very simple form.

(To be continued.)

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The Easthampton Radio Station.

The Cutting and Washington Radio Corporation has recently opened up a new commercial radio coastal station at Easthampton, Long Island, U.S.A.

The location of this station was the first important consideration for the company's engineers and Easthampton was decided upon only after most careful study of the necessities of ships entering and leaving New York. It was found that with the great number of vessels coming into and leaving the harbour great difficulty was experienced in handling the radio traffic and it seemed advisable to locate a station at a point sufficiently distant from New York to avoid the interference and at the same time near enough to arrange all details of docking, transmitting of commercial messages and allowing ample time for making up of abstracts and other details of accounting.

Direct telephone and telegraph wires to New York, together with a selected corps of experienced operators, insure accurate and speedy trans-

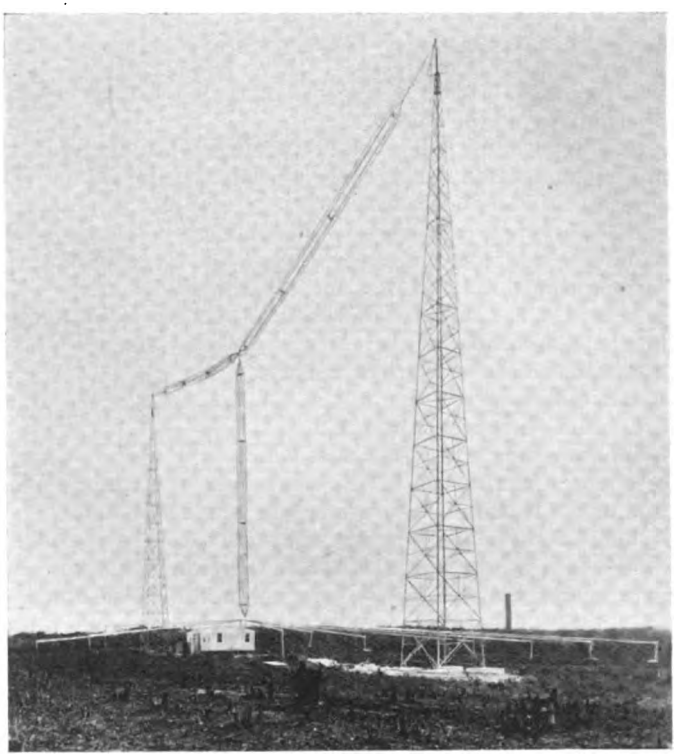

FIG. 1.—The Easthampton Radio Station.

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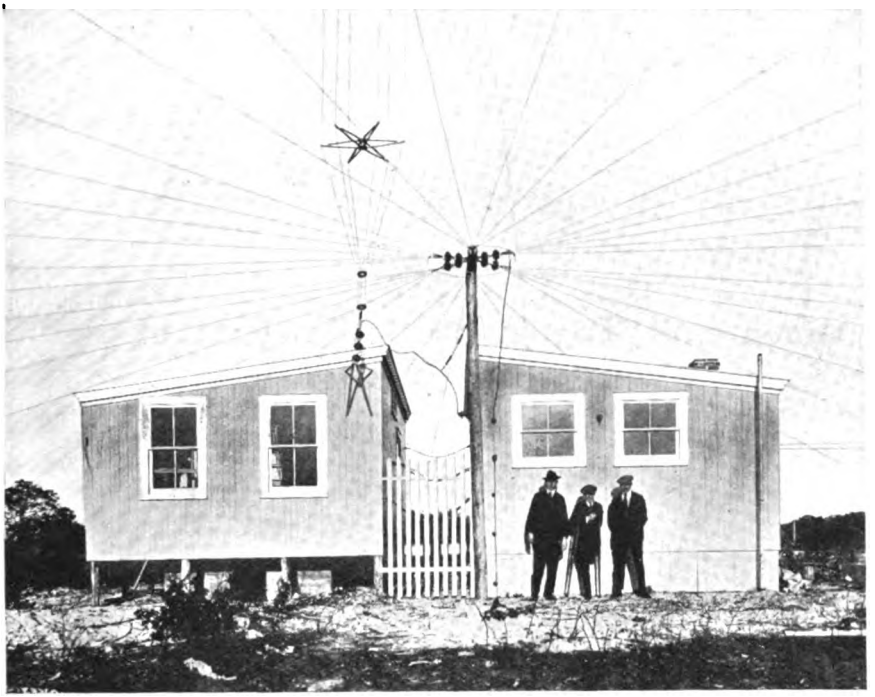

FIG. 2.—Easthampton Radio Station, showing buildings, and arrangement of aerial lead-in and counterpoise.

mission of all messages sent through this station, the call letters of which are **WSA.**

Easthampton is one of the fashionable summer resorts located on the south shore of Long Island. It is 103 miles from New York and is one of the earliest settlements on Long Island in that section, noted in the early days for its whaling interests.

The location of the radio station is on one of the highest knolls in the town about one mile from the shore. It occupies a plot of ground some six acres in extent. The two galvanised steel towers are 300 feet apart and are 165 feet high, surmounted with wooden masts which bring the total height of the antenna to 175 feet above the heavy concrete foundations.

The latest developments in antenna and counterpoise are used, the antenna being of the cage type found so efficient on battleships during the war; the counterpoise is a series of wires radiating from one corner of the radio building and practically covering six acres (Fig. 2).

The power supply is obtained from the local electric light company and is brought to the station in a conduit 1,200 feet long. Two thousand volts alternating current is stepped down to 220 volts from which a motor generator

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unit produces the 110 volts direct current used in the operation of the radio set. One of the well-known "Delco Light" units in conjunction with a storage battery is used as an auxiliary to provide against breakdown.

The radio "shack" is equipped with hot-water heating, shower and toilet facilities, rest room for operators off duty and complete office equipment for handling the clerical work necessary at the station.

The two photographs show the general arrangement of aerial and towers and the method of leading-in from the aerial and from the insulated counterpoise.

Nauen and Togoland: A Tragedy of Radio-Telegraphic Development.*

By Dr. R. ROSCHER.

INTRODUCTORY: WIRELESS ESTABLISHMENTS IN THE GERMAN PROTECTORATES.

For a long time insuperable obstacles prevented the execution of the plan of employing wireless telegraphy in the various German Protectorates. It was no easy matter to transport, work and keep in order such complicated apparatus and machines which, in the tropics, are exposed to special risks; increasing distances from the railway or the coast accentuated these difficulties. In the tropical Protectorates electrical disturbances were so violent that the receipt of messages was only possible on rare undisturbed nights and days. It was not until the musical quenched spark system was elaborated by the Telefunken Company that some hope was afforded of overcoming such difficulties. This system possesses various advantages, the chief of them being the production of a pure musical note which can be readily discerned amidst the hissing, gurgling secondary sounds caused by atmospheric disturbances. With the help of this system it became possible to construct a series of efficient wireless stations in the German Protectorates. In March, 1911, the wireless stations of Muansa and Bukoba on Lake Victoria, German East Africa, were opened. These were followed by a series of wireless stations on the coast, for instance in Swakopmund, Lüderitzbucht (German South West Africa), Duala (Kamerun), Dar es Salem (German East Africa), Lome (Togo), destined to communicate with ships trading with Africa.

Independent of these, there was constructed in the German South Sea possessions a network of large wireless stations. Its centre was the station on the island Jap in the Carolines which communicated through the German-Dutch cables with the general cable system. Further large wireless stations were erected in Rabaul (Gazelle Peninsula), in Nauru and Apia (Samoa).

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* Abstracted from *Archiv für Post und Telegraphie*—see Abstract No. 1426 in this issue.

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The idea suggested itself that it might be possible to utilise this new and increasingly important means of communication in order to effect a direct exchange of news between Germany and her colonies. This was all the more desirable, seeing that telegraphic communication between the German Empire and its African Protectorates was only possible through cables belonging to foreign companies. The dependence on foreign countries resulting from this state of affairs might, especially in times of political complications, be attended with the most disadvantageous consequences, not only from a military and political point of view, but also because of the harm it might inflict on trade and commerce. Even in times of peace, all news concerning political and economic events as well as that concerning details of administration was liable to the practical supervision and the one-sided colouring of foreign cables. No change in this undesirable state of things could be made except in respect of the West African Protectorates, which were to be joined up with the contemplated German South American cable from Monrovia. It was not to be expected that any German cable communication with German East Africa could be effected in the immediate future in view of the expense entailed and the great difficulties of obtaining the necessary landing points for the cables in foreign territory. An over-land connection with the German cable on the west coast would also have to pass through foreign territory, the Belgian Congo. Even if all the African Protectorates were joined by German cables and land lines with the mother country, the danger remained that these lines might in time of war be destroyed by the enemy, and the colonies thus be entirely cut off from telegraphic communication with the mother land.

PREPARATORY WORK. EXPERIMENTS BETWEEN GERMANY AND CENTRAL AFRICA.

Accordingly, in spite of the desirability of a wireless connection between Germany and her colonies, and in spite of all the technical progress made, the peculiar difficulties in the way of this connection were not to be underrated. The distances in question were of 5,500—6,000 km. Besides that, the receipt of messages was subject to the same violent atmospheric disturbances as in the case of the smaller stations working within the Protectorates or communicating with ships; these disturbances were bound to be even more appreciable on account of the larger receiving antennæ. In the given conditions, geographical and other, the first purely German wireless connection considered desirable was that between Germany and Kamerun (distance about 5,500 km). This question was discussed as early as June, 1908, in the "Committee for co-operation in the domain of wireless telegraphy" and subsequently on many occasions. From the outset it was evident that, notwithstanding the important contributions of science to progress in wireless telegraphy, the present problems could not be solved by theoretical investigations and laboratory research, but only by experiments carried out under practical conditions. And it was essential, if the experiments were to be carried out adequately and economically, to proceed from the less to the

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greater. The first experiments were thus arranged in the autumn of 1909 at the instigation of the Imperial Post Office, the Imperial Colonial Office, and the Imperial Naval Office, and with the means at their disposal the Telefunken Company had equipped its large experimental wireless station at Nauen, previously worked on the rare spark system, with the musical quenched spark, and raised the power supplied to the antennæ from 6 kW to 20 kW, that is to say, to the amount which appeared necessary, in the light of the experience then available, to cover a range of 6,000 km. As there was no station equipped with the latest technical devices to test the required size of the distant wireless station, the structure and height of its towers, the form and area of the antennæ, etc., an adequate substitute was provided by two Woermann steamers fitted with receiving apparatus in order to ascertain on the journey to and from Kamerun at what distances it was possible to receive a message from Nauen. The experiments carried out in the year 1909 with wavelengths of 1,000, 1,500, 1,600, and 2,000 m proved that, whereas isolated signals were received as far off as 4,600 km, a message as a whole was clearly intelligible at only half the distance of Kamerun and that single words were received as far as 3,600 km. On thoroughly investigating the result of the experiments, the conclusion arrived at was that the ship's antenna was insufficient for receiving at such great distances, because, on account of its small size, it picked up little energy ; and its efficiency was reduced owing to the necessity of loading it to the wavelength of the large wireless station. The necessity of good resonance between transmitter and receiver was confirmed by further experiments between Nauen and the large wireless station in Pola, built for the Austrian Government by the Telefunken Company (with waves of 1,500 and 2,000 m), since considerably greater receiving intensities were established than in communications with the ships lying close to the wireless station; with a wavelength of 1,600 m the signal intensity received was twenty-one times, and with a length of 2,000 m, twenty-eight times greater.

In the spring of 1910, experiments carried out with the steamer *Bosnia* on the journey to New York gave, with a 2,000 m wavelength, a range of almost 5,100 km.

After this result, it was felt that further successes might be hoped for when the experience thus gained was utilised. In the budget for 1911, therefore, 200,000 marks were provided for continuing the long distance experiments. In these renewed experiments an attempt had to be made to increase still further the power of the transmitting station, and to substitute for the small ship antenna one whose magnitude electrically speaking was approximately equal to that of the transmitting station. That was only practicable on *terra firma*. The Company offered to erect a corresponding receiving station, with a portable hut and the necessary apparatus, in Kamerun and to test it for receiving from Nauen. The establishment could not be set up on the Duala coast, since the Kamerun mountain, lying in the direction of Germany, would have formed an obstacle. Should the atmospheric disturbances in Kamerun prove too great, the experiment was to be tried in Togo.

In view of greater accessibility (telegraph line, interior railway) and more

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favourable geographic conditions, it was subsequently decided to make the initial tests at Togo. The Company was to find a suitable situation in the neighbourhood of Atakpame or Sakode by preliminary experiments. It was stipulated that the Company should further increase the umbrella antenna of the large wireless station at Nauen in order to raise its efficiency, should increase the power supplied to the antenna to 35—45 kW and should erect a second plant with an antenna power of at least 80 kW and increase the height of the lattice tower from 100 m to 200 m. The antenna power was raised to 35 kW in 1910—1911. For the duration of the experiments the Company was to set up for work in Togo a wireless receiving station corresponding to the dimensions of the establishment at Nauen. The antennæ of this station were to be supported by three lattice towers of angle iron, 75 m in height erected behind one another on stone foundations at distances of 225 m. From the tops of the towers the antenna wires were to be stretched horizontally in the form of a roof. Series of experiments lasting over forty-two days—apart from preliminary experiments with a balloon antenna in Togo—were stipulated, and the large wireless station at Nauen was to send two messages daily on forty consecutive days at fixed hours of day and night and with an antenna power of at least 80 kW. The Imperial Government might also demand tests with the 35 kW transmitter, and that experiments be carried out in Kamerun. If these tests were successful, the Committee resolved in May, 1911, to construct one large wireless station in Togo or Kamerun, and two large stations in East and South West Africa joining these two Protectorates with one another and with the large station, in Togo or Kamerun, which was to be constructed either then or later. The construction of these establishments in Africa was to be independent of the smaller wireless stations designed for coastal communication.

The situation ultimately decided upon by the Company's representatives for the receiving station in Togo was near Anae, a day's journey north of Atakpame, the terminus of the hinterland railway, on the road to Sakode. Instead of the easily transportable Rendahl masts, consisting of light steel tubes, which need no foundations, which can be readily set up in a short time and which had been selected that they might be set up at different places for the various tests, a heavier mode of construction had to be chosen. The Rendahl masts proved incapable of withstanding tropical conditions. A tornado overthrew two already constructed towers and shortly afterwards three completely erected masts were in their turn overthrown and destroyed. At last three frame masts of angle iron were set up capable, so far as one could calculate, of resisting any tornado.

In the night of June 6th—7th, 1911, for five minutes signals were for the first time successfully received from Nauen with the help of a captive balloon 150 m high which served to support the antennæ after the fall of the towers, the total length of the receiving wire being 300 m. Besides the signs from Nauen, the station had also received signs from the large English wireless station at Poldhu, although individual words could not be deciphered.

Thus for the first time radio-telegraphy bridged the long distance separating us from our African colony, and in little more than ten years progress

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had been made almost unparalleled in the annals of practical application of technical inventions. It is just this rapidity of success in the face of huge difficulties that earns the highest recognition for German achievements, far surpassing those of other countries at that time, in radio-telegraphy.

THE PRELIMINARY TESTS NAUEN—KAMINA (TOGO).

These successes were encouraging, although it was obvious that much remained to be done before communication could be thoroughly reliable.

The place for carrying out experiments was subsequently changed from Anae to a more favourable situation further south in Kamina, near Atakpame, in the immediate vicinity of the railway, 3·5 km from the terminus Agbonu.

In the meanwhile the work of increasing the dimensions of the station at Nauen had been continued; the height of the tower was increased to 200 m, and the horizontal antenna area from 15,000 m^2 to 140,000 m^2. The antenna was supported in the middle by the high tower, at its outer edge by eighteen wooden masts distributed in a circle at a distance of 400 m from the foot of the tower. The oscillating power of 80 kW was produced by the musical quenched spark system from an initial power of 200 kW and also in the form of undamped oscillations by means of a high frequency alternator.

In the beginning of January, 1912, further experiments followed with an antenna power of about 35 kW which was gradually raised to 80 kW, and with a wavelength of 3,000, 3,500, and 5,000 m. Although a few signals were received in Kamina from the wireless station at Norddeich, they could not be deciphered. On the other hand, nothing was received from Nauen. In February and March, however, a few coherent sentences of the text transmitted from Nauen with 50 kW antenna power were legibly received. Messages were also received from the European stations at Madrid (3,760 km), Rome (Coltano 4,200 km), Clifden (5,100 km), and Poldhu (4,900 km), from the African wireless stations Duala (1,100 km), Lüderitzbucht, Massana, Tenerife, etc., as well as from the American wireless station Glace Bay (7,100 km). The telegrams in these experiments were still legible when the atmospheric disturbances were twenty times as strong as the signals reaching the station. It was shown that a wavelength of 5,000 m was insufficient, and that it had to be increased to 7,000 or 9,000 m. In Togo a bent antenna was used with three masts 75 m high standing in a row, 200 m apart, in the reverse direction from Nauen; the capacity area was 35,000 m^2. Atmospheric disturbances in receiving were greater with long waves than with short. Morning hours proved better for receiving messages than evening hours; although the sound intensity in the morning was not so great as in the evening, atmospheric disturbances were weaker. The observations made by the wireless stations Duala, Swakopmund and Muansa in order to detect messages transmitted from Nauen met with no success.

The tests were long delayed by the collapse of the 200 m tower in Nauen on March 30th, 1912. A directive antenna was set up at Nauen consisting of twenty wires and supported by two frame masts of iron and two Rendahl masts each 120 m in height. It was not until the spring of 1913 that the

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experiments could be continued. In Togo the receiving antenna was supported by one tower 120 m, and three 75 m in height. The transmitting antenna at Nauen was at first 900 m, and later 750 m long and was supplied with a power of 100 kW. Tests were carried out on fifty-two days in all. Messages were received on thirty-seven days but only on seventeen days was there a legible text. The greatest number of text-words received in any one section of transmission was 535, the greatest sound intensity 7 ohms (parallel to the 4,000 ohm telephone receiver). The most suitable wavelength proved to be 4,500 m. Whenever the sound intensity was best, atmospheric disturbances were likewise most perceptible. The intensity of the disturbances was often less than 0·1 ohm. No law could be established regulating the occurrence and intensity of the disturbances. The results were, in spite of everything, considerably better than those in the spring of 1912 and gave ground to hope with some certainty that the proposed aim would be achieved.

Further tests were observed by wireless stations on board ships, and these likewise proved that messages might be satisfactorily received. On the journey to America signals with 50 ohms sound intensity were heard between 6 a.m. and 7 a.m. at a distance of 3,431 km and single words with 400 ohms sound intensity at a distance of 5,093 km. One ship's station heard, on the way to Africa, signals at a distance of 3,177 km during the night.

A second series of tests began on May 4th. Within a space of twenty-one days legible messages were received on only six. The experiments were therefore discontinued on May 24th. After this date attempts were made, by altering the antenna in Togo, to attain more favourable results, but without success. The sound intensity of the messages received in Togo did indeed improve as compared with that of the first experimental period; but the violent atmospheric disturbances occurring at this season of the year made it impossible to receive news except on rare nights.

The Telefunken Company then carried out on various occasions experiments to test more suitable antenna forms, different wavelengths and improved receiving apparatus. In the course of these experiments a far more satisfactory reception of messages in Togo was achieved than in those of the spring of 1913. In September, 1913, a frame mast of iron 250 m in height was begun in Nauen to replace the Rendahl masts of 120 m. It was finished by the end of March, 1914. In February, 1914, it was resolved to carry out a further series of tests extending over a space of forty days, and the conditions made by the Imperial Post Office (see below) were to be considered as having been complied with if, during each of three consecutive five-day periods, 1,200 words were received without a mistake. The tests took place as from February 10th. Messages were transmitted from 9 p.m. to 6 a.m. with a wavelength of 4,500 m, by means of the quenched spark transmitter, for twenty minutes commencing at every hour, and in addition, on Sundays, from 8 a.m. to 11 a.m. for sixteen minutes commencing at every hour with a wavelength of 9,400 m, and for sixteen minutes commencing at every half-hour with a wavelength of 6,800 m. No text could be received with the wavelength of 9,400 m, although the sound intensities were good,

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because the disturbances were far greater than with smaller wavelengths. The above-mentioned minimum was achieved in the first fifteen days of the experiments. In the first five-day period 1,619 words were received in Kamina, in the second, 1,721, and in the third, 1,540. From March 6th to March 18th inclusive, from five to ten telegrams were handed in daily by the Imperial Post Office to the station at Nauen for transmission to Togoland. The messages were received in Kamina by means of the already definitely completed receiving antenna which ran from north to south, was 3,755 m long, consisted of a wire rope about 11 mm thick, and was supported by three towers of 75 m in height and four towers 120 m in height (Fig. 1). The main tower at Nauen had reached a height of 200 m; the antenna was fixed at the time of the experiments at a height of 180 m. The

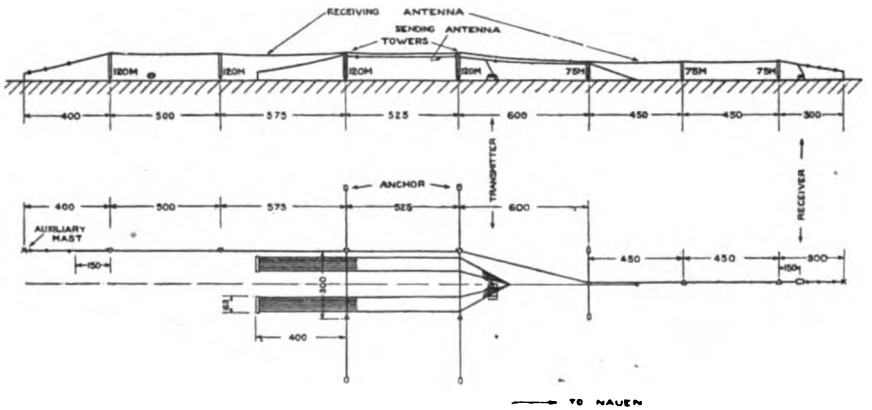

FIG. 1.—ELEVATION AND PLAN OF THE KAMINA ANTENNA.
(Dimensions are in metres.)

signals received in Kamina were amplified by means of Lieben valves; they were most distinct in the early evening hours (9 to 11 mid-European time) and in the early morning hours (5 and 6 o'clock mid-European time). From midnight till 4 a.m. thunderstorm disturbances were usually so great, or the signals arrived so weak, that they could not be received. The lowest sound intensity was measured with a shunt of 50 ohms, the highest with a shunt of 1 ohm, whilst the atmospheric disturbances were variously measured with shunts between 2 and 0·01 ohms. It was still possible to receive the text transmitted from Nauen when the intensity of the atmospheric disturbances (measured by parallel ohms) was not more than thirty times that of the arriving signals.

The wireless station Muansa observed the range tests. It heard, indeed, with a sound intensity of 200 ohms, signals which might reasonably be supposed to proceed from Nauen; but in consequence of atmospheric disturbances, which made themselves perceptible in the receiver by constant roaring, cracking, gurgling and hissing sounds, no coherent words could be heard; twice only individual letters were received.

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Owing to the satisfactory results obtained, the Company received from the Imperial Government the promised subsidy of 192,700 marks for carrying out the experiments in due form.

The first attempts at transmission from Kamina took place in the night of March 31st to April 1st. On this occasion the signals from Kamina were received in Nauen with a sound intensity of less than 1 ohm; the Lieben valve was used to magnify the sounds thirtyfold.

Shortly afterwards the writer of the present article heard in Nauen the signals so distinctly that he could receive the text without difficulty.

(To be continued.)

The Ionisation Potential of Helium.*

By B. S. GOSSLING, and J. W. RYDE.

In a paper recently read before the Physical Society of London, Dr. F. S. Goucher described measurements of the critical potentials for helium made by the method used in the experiments of Davis and Goucher, these being compared with the ionising potential of mercury vapour taken as a standard.

Assuming the ionising potential of mercury to be 10·4 volts, two critical potentials occur in helium, one at about 20 volts and the other at about 26 volts. These critical values agree well with those obtained by Horton and Davies.

The effect of radiation alone on the metal parts of the apparatus was studied under conditions which would yield evidence of use in the interpretation of the results obtained when the production of both ionisation and radiation was taking place simultaneously.

The conclusion was reached that the lower critical potential was a radiation potential, though some ionisation was produced also at this potential. This, however, was attributed to the presence of impurity, probably hydrogen. The higher critical potential was that at which ionisation took place.

In his paper Dr. Goucher gave an illuminating critical discussion of his results, while in the discussion of the paper, the present writers pointed out that material furthering this discussion may perhaps be found in some observations that they made last year in the laboratories of the G.E.C. (London) bearing on the question of the existence and effect of impurities.

The object of the experiment was actually to trace the variation with time of the effects of a small quantity of impurity known to be present at the beginning. The apparatus and method of observation was that described in a recent paper † which in the light of these later results requires qualifica-

* Abstract of a paper on "Ionisation and Excitation of Radiation by Electron Impact in Helium," by Dr. F. S. Goucher, and of the subsequent discussion at a meeting of the Physical Society of London on November 26th, 1920.

† G. Stead and B. S. Gossling, *Philosophical Magazine*, 40, pp. 413—425, October, 1920. RADIO REVIEW Abstract No. 1440 in this issue.

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tion in respect of the statement that the ionisation potential of helium is 21 volts.

The invariable final result shown in the cases here considered and in a very similar case described by Horton and Bailey,* is that no positive ions appear until voltages considerably higher than 20 or 21 volts are reached. This indicates that the lower ionisation point is not a characteristic of pure helium, but is due in some way to an admixture removable either by particularly thorough exhaust, or, as we have found, by the discharge itself.

The observations were made on about a dozen valves all of which behaved in a generally similar manner. These were subjected to a more severe exhaust with heating by electronic bombardment lasting an hour or more on a better pumping system than that used by Stead in the earlier case, but

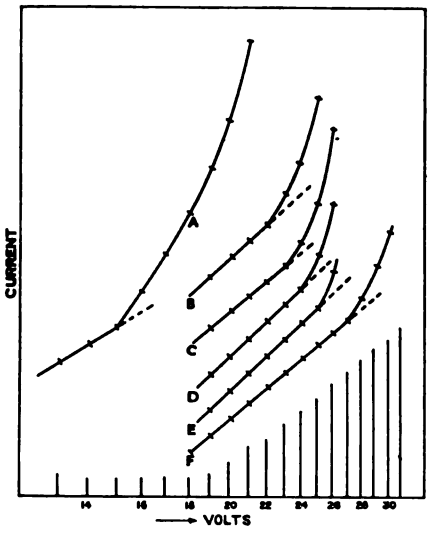

FIG. 1.

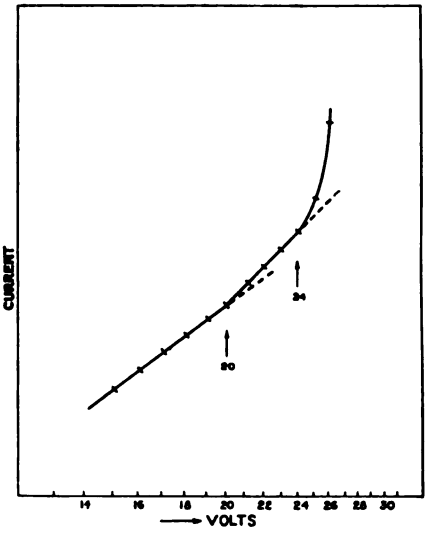

FIG. 2.

after filling with helium to 0·7 mm pressure they were generally sealed off instead of being left over charcoal and liquid air.

Taking the current voltage curves for a typical case and plotting the logarithms of current and voltage so that the " no gas " curve is very nearly straight, and the curvature at the various voltage values where ionisation sets in correspondingly more distinct, we find (Fig. 1) first a pronounced breaking away from the " no gas " curve at about 15·5 volts, indicating the presence of a very considerable amount of impurity presumably hydrogen or carbon monoxide, or both. After half an hour's running, however, with an anode potential of 150 volts there is a very marked change, the curve obtained

* *Philosophical Magazine*, 40, p. 440, 1920.

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being very like Stead's with the critical point rather above 21 volts. But later curves taken after seven, nine and twelve hours show a further, but much slower, progressive change, and finally no positive ions are found to appear before 25 volts at the least. In some of the sealed valves the final critical voltage was well above this value, and there were two cases (see Fig. 1, Curve F) when the valve was left over liquid air where the first definite curvature is at 27 volts. In a few sealed valves (Fig. 2) curves were obtained showing, like Dr. Goucher's, two critical points, at 20—21 V and 24—25 V.

What was happening seems to be that with the exhaust treatment given, the valve was left in such a state that the impurities disappeared under the action of the discharge just as they would have done had the helium not been there.

Pumping with the electrodes cold will not remove the last traces of impurity, nor will charcoal, as Dr. Goucher and Mr. Stead agree. Very possibly the impurity is " condensed " on the surfaces of the electrodes and is ionised *in situ*. The use of gauze electrodes of large total surface would favour this. A given quantity so condensed would give many more ions than the same amount spread throughout the tube.

On the other hand, prolonged passage of the discharge does as a first step put a stop to the formation of positive ions between 15 and 20 volts, apparently by removing the impurity, even in a sealed tube, to a place where it is no longer ionised by impact. Above 20 volts the impurity may still be accessible to helium radiation for a time, but ultimately its effects disappear and we are left with an ionisation at between 25 and 27 volts of which there is a better probability that it is really due to helium.

The considerations here put forward seem to apply to the recent work of Compton * equally with that of Dr. Goucher.

Measurements of Radiation of Radiotelegraphic Aerials.

By G. VALLAURI.

1. General Remarks.—It is well known that for the emission of a radiotelegraphic signal, a transmitting aerial is used (called also: sending antenna, oscillator, radiator, etc.) in which either damped or undamped oscillatory currents are set up. It is also well known that of the power P, which must be given to the aerial in order to maintain the oscillations, a portion P_p (usually very preponderating) is dissipated locally, owing to the resistance of the earth connection, the metallic resistance of the conductors, the parasitic currents induced in the surrounding bodies, the corona effects,

* *Philosophical Magazine*, 40, p. 553, 1920.

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the dielectric hysteresis in the insulators, and in general by the effects of every phenomenon which causes a local consumption of energy. But another portion of the power supplied to the aerial is not dissipated locally; it is spent in the creation of electromagnetic waves which are propagated over the surface of the earth, and produce in the aerial of the receiving station the phenomena which allow the reception of the signal. This second portion of the oscillatory power communicated to the aerial, represents the useful effects in connection with radiation and it is called the "radiated power, P_i." The relation between it and the total power is called, therefore, the efficiency of radiation of the aerial; $\eta_i = \frac{P_i}{P}$. This efficiency, in its turn, is only a factor of the overall efficiency of radiotelegraphic transmission, as it concerns only one of the many transformations of energy which the transmission requires—namely the conversion from the condition of energy of an oscillatory current circulating in a conductor to that of electromagnetic waves which are propagated over the earth's surface.

The knowledge of the radiation efficiency is a very important element in projects of aerials and for the working of plants; it requires the measurement of the total oscillatory power P supplied to the transmitting aerial, and the measurement of the power P_i radiated by it. It is with the measurement of radiation which we wish to deal in this note since it represents a very interesting aspect of the rapid progress accomplished by radiotelegraphy in these last few years, after having thrown overboard empirical criteria very often rough and sometimes erroneous and adopting instead more accurate quantitative methods of investigation.

2. Radiated Power.—Since the electrical magnitude which usually can be measured most easily in a transmitting aerial is the effective value I of the oscillatory currents in the neighbourhood of the earth connection (that is to say in most cases in about the centre of the oscillator) the total oscillatory power P supplied to the aerial is usually expressed as a function of the current I and of a total equivalent resistance R which satisfies the relation.

$$P = RI^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The distinction between the power P_p dissipated locally by all the causes of loss of energy mentioned above and the radiated power P_i can then be made by the consideration of two distinct parts, R_p and R_i, of the total resistance $R = R_p + R_i$, putting

$$P = P_p + P_i = R_pI^2 + R_iI^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The determination of the radiated power P_i is thus referred to that of the radiation resistance R_i, when also the intensity of current I is measured; and the efficiency of radiation becomes

$$\eta_i = \frac{R_i}{R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

We cannot see how it would be possible to measure directly the radiated power by the means at present available to science. It would be necessary

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to use an apparatus, capable of integrating in the unit of time the flow of energy through a closed surface embracing the oscillator, without its presence causing perturbations in any way to the development of the phenomenon.*

In reality the measurement of radiation reduces itself to the measurement of an electromagnetic field carried out at a certain distance from the oscillator, remembering that from the knowledge of the electromagnetic field, Poynting's theorem allows us to deduce the flow of energy through a surface element surrounding the point considered. The problem however, would be extremely difficult, if no hypothesis could be made as to the form and distribution of the electromagnetic field, because in such a case we should have to repeat the determination of Poynting's vector for all the points of a closed surface embracing the oscillator and we should have to make the integration over the same. On the other hand a single determination may be sufficient, when the figure of the field is already known which the oscillator produces and which depends on the form of the said oscillator.

* Here it is necessary to observe that the very definition of efficiency of radiation or, if it is so desired, the distinction between radiated power P_i and power dissipated locally by the effects of the losses P_p is not absolutely exact in the case of ordinary radiotelegraphic aerials earthed at one end either directly, or even indirectly through the intermediary of a capacity counterpoise. In fact in such a case it is difficult to define the shape to be given to the limiting surface across which the flow of the radiated energy should be measured. This is owing to the effect exerted by the earth and it can be emphasised by the help of Figs. 1 and 2, which represent diagrammatically a simple vertical aerial traversed by persistent oscillations, the

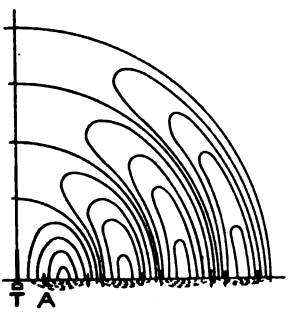

FIG. 1.

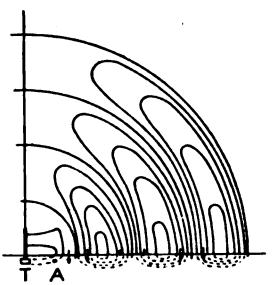

FIG. 2.

approximate form of the lines of the electric field at the moment of no current (Fig. 1) and at the moment of maximum current (Fig. 2). Those lines, which are lines of the electric field in the air, are closed, through the conducting soil, by lines of electric current (dotted in the figures). If the soil were infinitely conducting, the lines of current would not give rise to any loss and they would be limited to a surface stratum infinitely thin. But as the soil, on the contrary, is an imperfect conductor the currents which are set up in it give rise to losses. The power corresponding to these latter is a portion of the total power P supplied to the oscillator, but is it to be attributed to the power lost locally, P_p, or to the radiated power P_i? To this question we might reply that the losses due to the currents, which are closed on the earth conductors T (Fig. 1) of the aerial, still belong to the aerial losses P_p, whereas those due to the currents which are closed exclusively through the lines of the field in the air, form a portion of the radiated power P_i, inasmuch as they correspond to energy subtracted from the waves

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3. Radiation of the Dipole.—The simplest case of a radiator is that of the so-called "dipole" that is to say of an ideal oscillator (Fig. 3) of length $2h$, in which it is supposed that the whole capacity is concentrated at the ends, so that at a given instant the same value can be attributed to the current for the whole length of the oscillator. If the current I is simply a sinoidal function of time with frequency f or with the wavelength $\lambda = \frac{u}{f}$ (where u represents the speed of propagation of the electromagnetic waves or the speed of light), it is known that in a point M placed at a distance d from the oscillator, much greater than its length ($2h\ d >> 2h$), the electric field F and the magnetic field H are two alternate sinoidal vectors orthogonal to each other and with reference to d, orientated in such a way that F lies in the plane of d and of the oscillator, and H is therefore perpendicular to the said plane. The two vectors have the same phase and this is displaced with respect to the phase of the current I, by a retardation in proportion to the distance d. The effective values of the two vectors are expressed respectively thus:

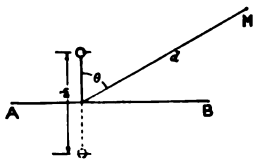

FIG. 3.

$$\left.\begin{aligned} F &= 4\pi\sqrt{\frac{\mu}{\epsilon}} \cdot \frac{Ih}{\lambda d} \cdot \sin\theta \\ H &= 4\pi \frac{Ih}{\lambda d} \cdot \sin\theta \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (4)$$

where μ and ϵ are the magnetic permeability and the electric permeability (or dielectric constant) of the medium, connected with the speed of propagation by the well-known relation $u = 1/\sqrt{\mu\epsilon}$. It is understood that in the relations cited, every dimension must be expressed in units belonging to the same system of measurement.*

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propagated in space and therefore already radiated by the oscillator. But not even this distinction allows us to define the closed surface across which the flow of energy corresponding to the radiated power P_i should be measured, because it is easy to see, that there are infinite points (as that indicated in the figures by A) in which the losses belong alternately to one category (Fig. 1) or to the other (Fig. 2) according to the moments in which they are considered.

This discussion however has no appreciable practical importance, because according to what experience has demonstrated, the conductivity of the materials constituting the crust of the earth is for the most part so high that up to a distance of many times the length of the wave of the oscillator, the power subtracted from the waves by the losses in the soil, is negligible. In fact it happens that between such limits the intensity of the electromagnetic field decreases in inverse ratio to the distance, as should happen where there are no losses in the soil. The result is that the energy radiated is detached from the transmitting aerial almost exclusively from the hemisphere above the earth's surface and that, during the propagation, a small portion of it, falls progressively into the soil where it is consumed by the effect of losses, giving rise to those phenomena of attenuation which can only be begun to be noticed experimentally at distances of the order of hundreds of times the wavelength.

* It must be pointed out once more, how necessary is it to express general relations in such a way as shall satisfy the condition of homogeneity and therefore that they shall be valid in

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Considering only the radiation emitted by the half oscillator of height h in the hemisphere above the equatorial plane A B (which may be identified with the surface of the earth supposed flat and of perfect conductivity), and applying Poynting's theorem to the hemispherical surface with radius d, we deduce the expression of the radiated power:—

$$P_i = \frac{(4\pi)^2}{3}\sqrt{\frac{\mu}{\epsilon}}\left(\frac{h}{\lambda}\right)^2 I^2 = R_i I^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

in which wishing to express P_i, I, and R_i in practical units (watts, amperes and ohms respectively) we get for the ether and appreciably also for the atmosphere $\sqrt{\frac{\mu}{\epsilon}} = 3 \times 10$ or

$$R_i \text{ (ohms)} = (4\pi)^2\, 10\left(\frac{h}{\lambda}\right)^2 = 1{,}600\left(\frac{h}{\lambda}\right)^2 \text{ approximately} \quad . \quad . \quad . \quad (6)$$

4. Effective Height of Aerial.—The case of the simple linear oscillator of length $2h'$ (Fig. 4) can be treated when oscillating with its natural wavelength in an analogous manner to that of the dipole. It is sufficient to substitute $\frac{2h'}{\pi}$ for the value h, as it is easy to deduce by attributing to the current no longer a uniform distribution along the conductor, but rather a sinoidal distribution, applying equations (4) to each element of the said conductor and integrating.

In the two cases just mentioned we see how easy it is when the effective length of the oscillator $2h$, the wavelength λ and the current intensity I are known, to deduce the electric and magnetic field without the need of other experimental data by (4) and the power radiated in a hemisphere by (5). Similarly, by measuring the electric field F or the magnetic field H, at a given point (r, θ) and knowing two only of the three dimensions, h, λ, I, it is possible to deduce the third. In particular by measuring λ and I for the oscillator or sending antenna, and measuring the magnetic field H at a given point (r, θ), the effective height h can be deduced.

The radiation measurements which are now being made in the technique of radiotelegraphy, are based precisely on the measurement of the magnetic field H (or of the electric field F) and on the deduction of h by the relations (4) and (5). They are based, therefore, on the convention of identifying, at

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any system of units. In practical formulæ with numerical coefficients, such as for example equation (6), which cannot satisfy such a condition, the units by which it is intended to measure the various dimensions should be always stated.

From this point of view there are to be found, very often, in scientific memoirs and in text-books, certain oversights which can easily lead one into error. For example, nowhere, if I am not mistaken, is the first of equations (4) expressed in the manner shown here, but instead of the factor $\frac{\mu}{\epsilon}$ sometimes the symbol of the speed of light u is found (Zenneck-Seelig, "Wireless Telegraphy," *McGraw-Hill Publishing Company*, 1915 edition, p. 35). In this way however the equation is not homogeneous.

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least approximately and in connection with distant effects, the effective aerial with half a Hertzian dipole and by calling the height of radiation or effective height h of the aerial that of the equivalent half dipole, or of a half dipole connected with the earth, which carrying the same current I, with the same wavelength λ, gives rise at that point to the same electromagnetic field. On the basis of this definition and on what has been stated above, the effective height of a simple linear aerial (Fig. 4) oscillating with its own wavelength, is $h = \frac{2}{\pi} h'$ where h' is the geometric height of the aerial, that is to say, the length of the conductor which constitutes it.

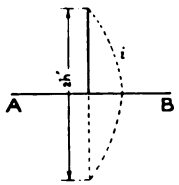

FIG. 4.

5. Receiving and Measuring Aerials.—The measurement of the magnetic field H (or of the electric field F) is usually effected for sending antennæ connected with the earth, by a receiving aerial which is itself placed in proximity to the ground, at such a distance and in such a position that we may consider the earth as flat and therefore put $\theta = \pi/2$. The receiving aerial may be of either of the two types most in use to-day, that is to say, a half oscillator connected with the earth like the sending antenna, or a frame aerial with one or two coils, polygonal in shape isolated from the earth and constituting a closed circuit. In both cases the measurement of the field is related to a measurement of the effective intensity of the received current I_r, on the basis of the following considerations: If the receiving aerial is a half oscillator connected with the earth; if it is admitted that the electric field F is vertical; if the aerial is identified with a half dipole of height of h_r; and finally, if persistent oscillations be considered, we get that the E.M.F. induced by the waves in the receiving aerial is

$$E = h_r F \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

If, on the other hand, the receiving aerial is a plane closed circuit, lying in the vertical plane which includes the receiving station and the axis of the sending antenna (or forming with it an angle α), if it is admitted that the magnetic field is perpendicular to this plane and if the horizontal extension of the receiving aerial is small in comparison with λ, the E.M.F. induced in the aerial is

$$E = 2\pi \frac{u}{\lambda} S_r \mu H \cos \alpha \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where S_r is the total area of the receiving closed circuit (or, if the circuit consists of several co-planar or parallel spirals, S_r represents the sum of their separate surfaces, *i.e.*, if there are N equal coils each having a surface of S_1, $S_r = NS_1$*).

* An equation exactly equivalent to (7) can be obtained expressing the E.M.F. as a function of H instead of F, depending on the fact that the receiving aerial cuts the lines of magnetic flux which are propagated horizontally. In the same way, (8) can be replaced by a relation

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In both cases, the current I_r, generated by the induced E.M.F. E, is expressed by

$$I_r = E/Z_r \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where Z_r represents the total impedance of the receiving oscillatory circuit, and, in the case in which the receiving circuit is tuned to resonance,

$$I_r = E/R_r \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9a)$$

where R_r is the total equivalent ohmic resistance, that is to say, that which represents all the losses of energy to which the oscillation induced in the receiving aerial is subject.

It is seen that the determination of the electric field F, by (7), requires first of all, the knowledge of the effective height h_r of the receiving aerial at the given frequency. This can be deduced, λ being given, from the geometric dimensions of the aerial if they are very simple and well defined, or it will have to be found by special radiation experiments.*

In the case of the closed circuit and of the relation (8) it is likewise necessary to know the geometrical dimensions of the said circuit. In both cases then, the measurement of the received current I_r is required as well as that of the impedance Z_r (*i.e.*, of the resistance R_r if the receiving aerial is adjusted to resonance) of the receiving circuit.

6. Measurement of the Received Current.—The measurement of I_r is a particular case of the measurements of weak oscillatory currents which very often occur in radiotelegraphic technique. When it is a question of extremely small currents as in the case of the measurement of the electromagnetic field produced by very distant emissions, it is necessary to resort to indirect methods,† but in the ordinary case of measurements of radiation which are carried out, as we shall see, at distances of two or three wavelengths from the transmitter, the I_r values to be measured are generally of the order of tens, hundreds and even thousands of microamperes and therefore one can have recourse advantageously to direct measurements by thermal methods. These are carried out generally by one of the following methods :—

(*a*) Inserting in the aerial circuit the heater wire of a thermo-couple and connecting the ends of the couple to a galvanometer.

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in terms of F, deduced by the consideration of the size and phase of the elementary E.M.F.'s produced by the electric field in every element of the receiving closed circuit. These relations naturally satisfy the relation $\sqrt{\epsilon}F = \sqrt{\mu}H$ which is deduced from (4).

* According to a combination method proposed by Commander Pession, if there are three aerials available, of which at least two can function as transmitters and two as receivers, it is possible to determine with three measurements the effective height of each of the aerials. (See an article by G. Pession, " A Particular Case of the Measurement of the Effective Heights of Radiotelegraphic Aerials," which will be published in a forthcoming issue.)

† G. Vallauri, " Measurement of the Electromagnetic Field of Transoceanic Radiotelegraphic Waves " (*L'Elettrotecnica*, 7, p. 298, June 15th, 1920), and Publication No. 9 of the Royal Naval Electric and Radiotelegraphic Institute.

[See also RADIO REVIEW, 1, pp. 652—655, October, 1920.]

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(*b*) Inserting in the aerial circuit the heater wire of a " Duddell " thermo-galvanometer, which is merely the combination in a single instrument of the couple and galvanometer.

(*c*) Inserting in the aerial circuit a bolometer connected to a Wheatstone bridge, which allows the variations of resistance of the wire to be measured.

It may be said that these three methods are given in the order of increasing sensitiveness. Naturally the greater the sensitiveness the greater are the difficulties and the greater the delicacy of the measurements. The first method can be brought to be equal to the second, making use of good couples enclosed in vacuum bulbs and very sensitive reflecting galvanometers, but the difficulties of the two methods are then equivalent. In the case of very powerful transmissions, of short distances and very extensive receiving aerials, I_r may attain such a considerable value that it can be easily measured with direct reading instruments, such as Duddell's thermomilliammeter or even with a hot-wire ammeter of great sensitiveness. As is well known, if it is desired to attain the maximum degree of sensitiveness, it is necessary to choose for the heater of the couple, or of the thermogalvanometer, or for the bolometer wire, a resistance of the same order of magnitude as the total impedance of the aerial.

All these instruments, besides, must be calibrated in order that it may be possible to obtain from their readings the effective value of the I_r current. The calibration can be easily carried out by direct current in the case of the thermogalvanometer. In the case of the couple, on the contrary, the calibration may be rendered uncertain by a direct shunting of direct current through the galvanometer, independently of the thermoelectric

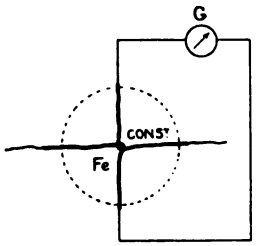

FIG. 5.

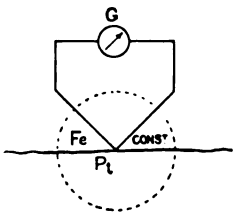

FIG 6.

phenomenon. This defect is so accentuated in the " cross " couples (Fig. 5) that calibration by direct current is rendered unreliable: in fact, it often happens that, on reversing the direct current, the galvanometer deviation not only changes in amplitude, but even in sign. On the other hand, in the case of couples where the junction makes a very limited contact with a continuous heating wire (Fig. 6) the deviation of the galvanometer depends almost exclusively on the thermoelectric effect; this can be checked by reversing the direct current and verifying that the two deflections thus ob-

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tained differ very little or not at all. For the purpose of calibration the mean of the two deflections is taken.

In the case of the crossed couples it is necessary to effect the calibration with alternating current. The same holds good for the bolometer, on account of the use of the bridge device which would be directly perturbed by the continuous calibration P.D. This is the greatest drawback of the bolometer, because as it is a question of very weak currents, it is usually necessary to fall back on the thermogalvanometer for the comparison of alternating currents and then calibrate in turn the thermogalvanometer by direct current. Moreover the bolometer is exposed to the drawback that one portion of the alternating current communicated to the heating wire tends to propagate itself to the other branches of the bridge and one portion of the direct current of the bridge tends to pass into the frame-shaped aerial and this renders necessary the use of inductances and capacities for protection.

On account of all these reasons it has been considered opportune to prefer usually the use of the thermogalvanometer which combines the advantages of simplicity and ease of handling with those of precision and sensitiveness.

(*To be continued.*)

The Lafayette Radio Station.*

The Lafayette radio station situated at Croix d'Hins 25 km to the south of Bordeaux is now completed and was put into service on December 18th, 1920. The construction of the Croix d'Hins station was decided upon during the war and dates back to the last months of 1917 after the intervention of the United States in the European conflict. The transatlantic cables which were liable to accidental damage or to attempted destruction by the enemy constituted a precarious means of communication. France it is true had at its disposal the radio stations at the Eiffel Tower and at Lyons, but the normal transmission programmes of these stations for military communications and propaganda work were already too full to admit of a further extension of their traffic.

From the first test carried out with these stations to determine their suitability for this purpose, it was found that the station at Lyons was the one best adapted to ensure regular communication. Its signals were generally heard in America as strongly as those from Nauen, but it was well known that during the summer season when atmospherics were prevalent the reception of European stations, German or French, left much to be desired. The reception of the signals from this station was made the subject of special study by French radio engineers who proceeded to America for this purpose.

From the information which they were able to gather it was evident that in the event of an interruption of the cable communications, the Lyons station even if assisted by the one at Nantes, which had just been completed

* Abstracted from information contained in the articles referred to in Abstracts Nos. 1423, 1424, and 1425 (in this issue).

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by the French naval service, could not deal with the enormous traffic which would fall upon it.

It was therefore decided to build a new radio station capable of ensuring at any season and at any hour a permanent service with the United States and, at that time, devoted entirely to military needs. To achieve the desired results it was estimated that it would be essential to employ a current of about 500 amperes in an antenna supported by towers 250 metres high, the antenna capacity being of the order of 0·05 mfd and the resistance being not greater than 1·5 ohms. This estimate of the requirements which at the time seemed somewhat exaggerated has been proved by subsequent tests to be perfectly justified.

For the construction of the station the United States Navy and the French military radiotelegraphic organisations combined together, the former undertaking to provide the radio frequency generators, and their accessories as well as the antenna towers, while the latter undertook the provision of the earthing system, the erection of the antenna, the construction of the buildings and the power lines from Bordeaux to Croix d'Hins. The negotiations that took place on the subject resulted at the beginning of 1918 in the conclusion of an agreement fixing the character of the collaboration between the two nations, and the work was actively pushed forward from that date.

The buildings and towers were partly completed when the Armistice of November 11th, 1918, temporarily interrupted the Franco-American col-

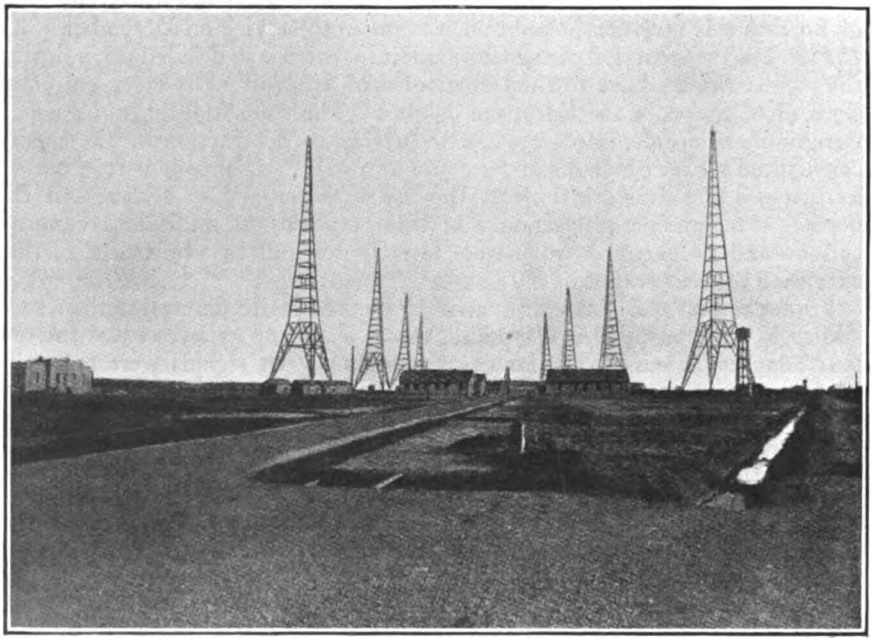

FIG. 1.—General View of the Lafayette Station.

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laboration. At that time the United States offered either to take back or to hand over to France their material not then installed but the French Government preferred to profit by the work already accomplished and to carry on the completion of the work. A Convention dated February 11th, 1919, between the two countries fixed the conditions for the completion of the station. After an interruption of six months the American Navy resumed its work with the result that the towers were completed by the end of 1919, while in August, 1920, the station was ready to undergo its preliminary tests.

The station occupies the site of an old aviation camp of about 1,230 acres adjacent to the Bordeaux-Arcachon-Bayonne railway. A central roadway through the side leads to the main building marked "Radio Building" in Fig. 2, passing a large workshop containing a transformer sub-station and

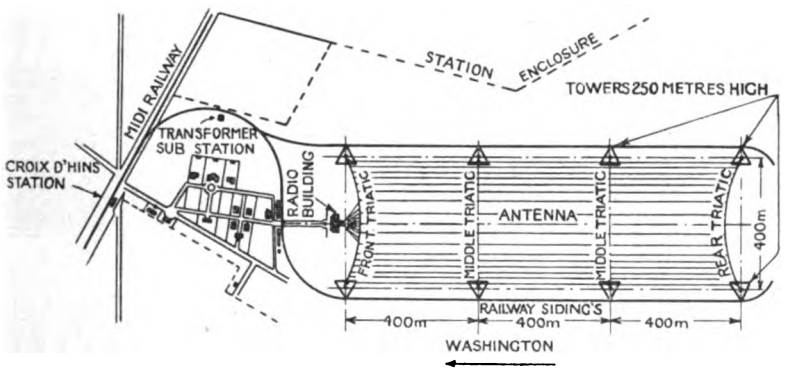

FIG. 2.—Plan of the Lafayette Station and Aerial.

the accumulator rooms as well as a store. Four buildings are devoted to a laboratory, a canteen and accommodation for the staff. A transformer station (stepping down from 50,000 to 2,200 volts), with accommodation for the electricians, accommodation for the chief officer of the station and his assistant, a garage and the water towers complete the list of subsidiary buildings. A branch railway line about three miles in length leads to the stores, the station and the eight towers, and is connected with the lines of the Chemin de fer du Midi. A near view of the station buildings is given in Fig. 3.

Both by its size and its height the antenna of the Lafayette station constitutes one of the largest in the world. It is of the same height and size as that to be employed at the French colonial station at Saigon. It consists of a horizontal part having sixteen parallel strands and a vertical down lead with ten strands. It is supported by eight steel towers 250 metres (830 feet) in height arranged in two rows 400 metres (1,330 feet) apart, the towers in each row being also 400 metres (1,330 feet) apart. The area covered by the antenna is thus 480,000 square metres (118 acres). The two central cross

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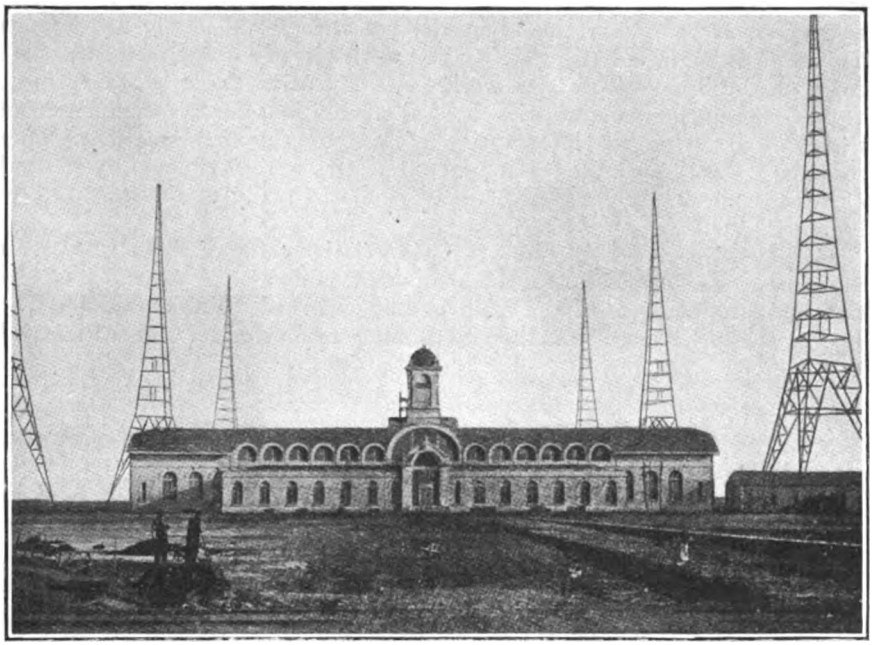

FIG. 3.—View of the Station Buildings.

supporting wires, or triatics, of the antenna each carry at their point of attachment to the towers a normal load of three tons and have a sag of 25 metres (82 feet). They are designed so that even with a high wind the load which they have to carry remains well below their safe working stress. Double insulators are used for the first triatic cable and single insulators for the remaining three. Each insulator consists of a porcelain cylinder 180 cm (71 inches) long, weighing 160 kg and having a tensile strength of about 15 tons. The antenna is designed for a normal wavelength of from 20,000 to 25,000 metres. The towers are of the American navy type, being of tripod form and having a triangular base of 65 metres (212 feet) side.

The earth connection consists of a double system of buried plates and tubes. Copper plates 115 cm × 140 cm (45 inches × 55 inches) are buried 1½ metres (5 feet 10 inches) below the surface, and are each provided with lugs for connection to the neighbouring plates. The tubes are each 25 metres (82 feet) long and are arranged in two circular rings, the first having forty tubes connected together and each connected to the buried plates and the second having eighty tubes also connected together and to the plates. In addition to the above a further ring of earth plates has since been added and to still further improve the earth connection they were joined to the towers and to the railway lines.

The two arc converters which were manufactured by the Federal Telegraph Company form the most interesting part of the installation.

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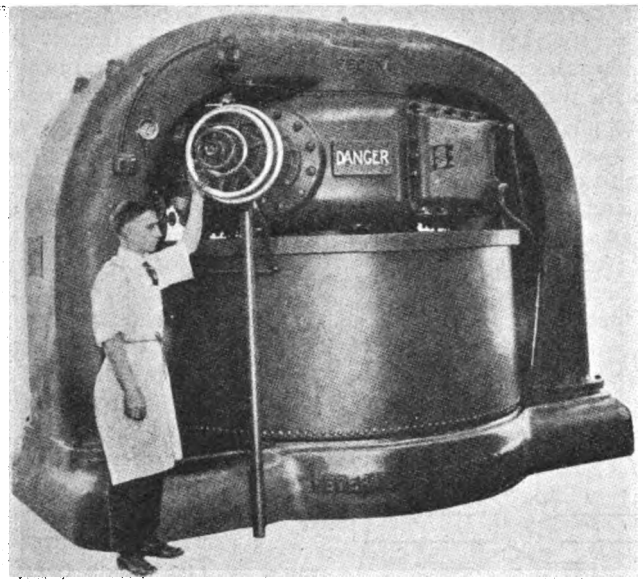

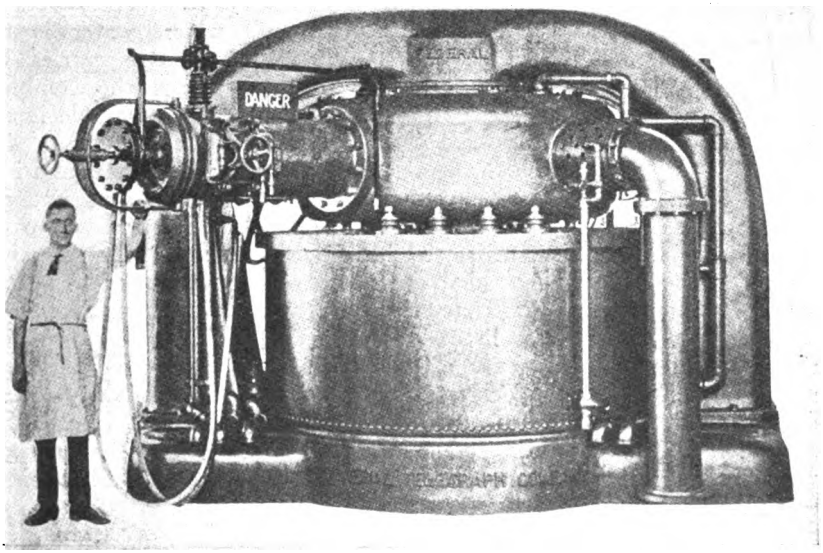

FIGS. 4 AND 5.—The 1,000 kW Arcs. Cathode and Anode Sides respectively.

While the arc at the Lyons station yielded an output of 180 kW high-frequency energy in the antenna circuit those at the Lafayette station can each give 500 kW in the aerial. A further comparison of the two arcs is also interesting. The former has a total weight of about 7 tons of which the

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magnetic circuit contributes 4 tons. The second weighs approximately 80 tons, seventy being contributed by the magnetic circuit. Apart from the remarkably robust character of the Federal Company's arc the disproportion between the weights of the two types arises from the fact that in the French arc the magnetic circuit is designed only for the conditions under which the apparatus is normally intended to be used, whereas the American arc is designed to operate over the largest possible limits and can be used in very diverse circumstances. Two views of the arc are given in Figs. 4 and 5.

With an air gap of 18 cm (7·1 inches) the magnetic field strength can reach the value of 17,000 gauss. The magnetic circuit carries two windings one being joined in series with the supply circuit to the arc while the other is fed from a special auxiliary machine. The second winding can either add or oppose its effects to that of the main winding so that a fine adjustment of the field strength is thus possible. The general arrangement of the magnetic circuit is indicated roughly in Fig. 6. The main details of the arc are as follows :—

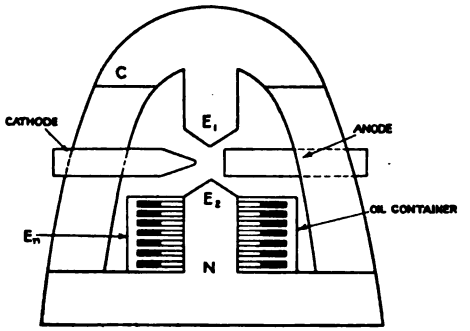

FIG. 6.—Diagrammatic Arrangement of Magnetic Circuit of Arcs.

The anode consists of a tube 2 cm (0·79 inches) diameter through which water is circulated, the anode carrier being insulated from the combustion chamber. The cathode is a carbon cylinder of about 4 cm (1·58 inches) diameter and is supported by a holder which by movement in conical guides under the control of a handwheel can grip or release the carbon rod. Two other handwheels enable the carbon to be moved backwards or forwards or clamped in position while a fourth operates the field rheostat of the generator supplying the auxiliary magnetic field of the arc. The combustion chamber is provided with double walls and is water cooled. The waste gases from this chamber pass out through a collecting pipe 30 cm ($11\frac{3}{4}$ inches) in diameter to special exhausting pumps while precautions are also taken to prevent damage in the event of explosion. Both water and oil circulation systems are provided for cooling the arc, the latter serving for cooling the magnetising windings. By appropriate valves the circulating systems can be connected to either of the arcs.

The power used in the station is furnished exclusively by the Société de l'Énergie Électrique du Sud-Ouest in the form of alternating current at 50,000 volts. No emergency supply installation has been provided. The power is supplied from a special central station which has been built at Floriac near Bordeaux. In case of necessity the supply may be taken from a transformer station at Cenon near Bergerac on the River Dordogne. The power lines cross the Garonne by a 500 metre span after which they have a

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run of 28 km ($14\frac{3}{4}$ miles) to the transformers at the radio station. A special transformer station has been installed near the radio station and contains two 3-phase transformers each of 2,500 kVA capacity which may be connected to the lines either singly or in parallel. These transformers reduce the voltage to 2,200.

A smaller transformer sub-station has also been installed in the workshop of the station for supplying the auxiliary services other than the main radio apparatus. In this sub-station two 2,200/200 volt transformers have been installed for feeding motors driving battery charging generators and the workshop motors. In a separate room a 220 volt 350 AH battery has been installed and is used solely for emergency lighting.

Four cables are run from the main transformer station to the busbars in the radio building to which are connected two 1,000 kW, three-phase, 2,200 volt, 50 cycles, synchronous motors which drive the generators furnishing the continuous current for the arcs. These motors are started up as asynchronous machines with a squirrel cage winding on the rotor under reduced voltage from an auto transformer. In addition to the usual indicating instruments these machines are provided with specially graduated meters connected to resistances incorporated with the windings of the stator so that the temperature of the windings is indicated directly. The 1,000 kW D.C. generators driven by these machines and used for feeding the arcs are compound-wound machines having six main and commutating poles. They give 1,250 volts when running at 750 r.p.m. and are provided with an exciter on the same shaft. They have an independent field winding fed from the exciter, a series winding on the main poles, a series winding on the commutating poles and a compensating series winding. All the series windings are provided with diverters. An overload relay is joined in series with each machine so that in the event of an overload it interrupts the auxiliary starting circuit of the arc and causes the contactors which short circuit the series resistances in the arc leads, to be opened.

The negative poles of the generators and the cathodes of the arcs are all joined to the main earthing system, the earth connections of the former being made through four resistances and an overload relay. The ends of these starting resistances are joined to four contactors by means of which they can be short circuited. The positive poles of the arcs are joined to the positive busbars of the machines through appropriate circuit breakers, so that the circuit from the machine thus comprises the series windings of the arc, the arc and the earth connections.

The starting controllers have eight positions which perform the following functions:—

(1) Opening of the water circulation valves.
(2) Opening of the valves admitting alcohol into the combustion chamber.
(3) Starting of the cathode driving motor.
(4) Closing of the circuits supplying the arc and the supplementary excitation of the arc.
(5) to (8) Short-circuiting of the four resistances in series with the arc.

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A safety arrangement is provided which prevents the arc being started up if there is insufficient pressure in the water circulation pipes, and which opens the arc circuits if the water pressure should fall below the predetermined limit. This apparatus consists of an ordinary pressure gauge provided with two contacts, the upper one of which when closed completes the circuit through the main contactor in the arc leads which is then automatically retained in the closed position. If the water pressure falls sufficiently to cause the lower contact to be closed the holding-on coil of the contactor is short-circuited and the main circuit of the arc thus interrupted.

The antenna loading inductance is constructed of large section flexible cable consisting of strands of wire twisted round a hemp core, the wire strands as well as the cable being insulated. The cable is supported round twelve insulators arranged in a ring on a concrete base, and the coil is placed in an hexagonally shaped room outside the body of the main building. This room is provided with a network of earthed wires to screen the main building from the inductive effects of the coil.

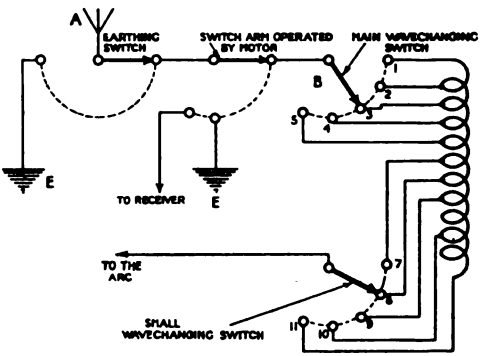

FIG. 7.—Wave-changing Switches.

The wavelength changes are effected by means of motor driven switch arms which are arranged in the manner indicated in Fig. 7. The contacts and switch arms of these switches are mounted on insulators on a switchboard near the loading coil. The switch arms are moved by a ¼-H.P. 115 volt motor through suitable gearing. The motor also operates a five-way rheostat in the field circuit of the 30 kW generator which provides the auxiliary magnetising current for the arc, so that the magnetic field-strength is automatically adjusted to a value appropriate to each wavelength.

On account of the fine sub-division of the aerial loading coil the resistance of the whole coil does not exceed 0·25 ohm. The inductance values when the small switch arm is on contact 11 (Fig. 7) are approximately as shown in the table.

Position of Switch Arm B.	Wavelength in Metres.	Inductance in Henries.
1 (whole coil)	23,460	0·003
2	21,240	0·0024
3	18,940	0·0018
4	16,420	0·0013
5	13,840	0·0009

For signalling purposes, at high speeds, the arrangements are briefly as follows—the first relay, operated by a Baudot telegraph relay, operates in its turn twenty-eight relays in two stages; these last operate seventy-eight signalling

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contactors arranged on a frame round the aerial loading coil. These contactors short circuit windings in series with one another, independent of but adjacent to the main coil, thus changing the effective inductance of the aerial circuit. The transmitting apparatus is controlled in Bordeaux by means of a Wheatstone transmitter with a Kleinschmidt perforator. The speed of signalling obtained up to the present has been fifty words per minute giving a total of 72,000 words per day. It is intended later to operate the station direct from Paris and in all probability high-frequency alternators of the Bethenod-Latour type will be installed.

The first tests of the station were made by the American Navy from August 21st to September 21st, 1920. When using the normal generator voltage the antenna current was found to exceed 500 amperes; it easily reached 600 amperes with a slight overload of the machines, and in all respects the whole of the installation operated in a satisfactory manner. Tests of long duration showed that the arcs are perfectly adapted to ensure a continuous traffic at high power. It is too early yet to give complete information on the commercial ranges which can be achieved by the Lafayette station but the reception tests which were carried out on the occasion of the testing of the station have yielded some interesting results. They were made by the most important American stations situated in various parts of the world—America, Hawaii, the Philippines, the Pacific Islands—and also by the French colonial stations. Most of the operators at these stations were only able to receive the long wavelength of 23,500 metres with experimental receivers and the majority of the tests were not picked up for a sufficient duration of time to enable satisfactory conclusions to be deduced. From these tests the following conclusions may, however, be drawn: firstly, that communication between France and America appears to be certain at all times and under all conditions; secondly, that for longer ranges it can be stated that at all points on the earth the Lafayette station can be heard every day, during the most favourable hours.

From measurements made at San Francisco it was found that the strength of signals received from Lafayette was from four to eight times the strength of the signals received from Nauen. Summarising then, it can be stated that from the commercial point of view the Lafayette station will be able to guarantee excellent communication at all times with the United States and practically always also with the French colonies.

In addition to the above advantages the station at Croix d'Hins will doubtless be of great scientific importance for the special study of high-power work and transmission problems as well as for meteorological and astronomical work such as the accurate determination of longitudes, while it will doubtless also serve to draw closer the ties of friendship between the two great Republics of France and America.

[See further notes on this station on p. 59.—ED.]

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The Physical Society's Exhibition.

The eleventh annual exhibition of the Physical Society of London, and of the Optical Society was held at the Imperial College of Science and Technology, Imperial Institute Road, South Kensington, S.W., on January 5th and 6th, 1921. As is the usual custom of this exhibition, it was open in both the afternoons and evenings of the two days, and in addition to the exhibits, discourses were delivered on various subjects. Among the exhibits, were a number of instruments, and apparatus of wireless interest, including testing and measuring apparatus for high and low frequency currents. Of these exhibits, a few particulars of the most important and interesting are set out below :—

MESSRS. H. W. SULLIVAN'S exhibits included the following :

C.W. Heterodyne Wavemeter.—A continuous-wave wavemeter with a range of from 600 to 6,000 metres which can be used also as a plain oscillation generator for use in the separate heterodyne method of C.W. reception.

The circuit used is shown in Fig. 1, the oscillatory circuit consisting of the variable air condenser C and the two variometers V_1V_2, the circuit being closed to high-frequency oscillations by the fixed capacity C_1 of a sufficiently large value not to appreciably affect its natural frequency.

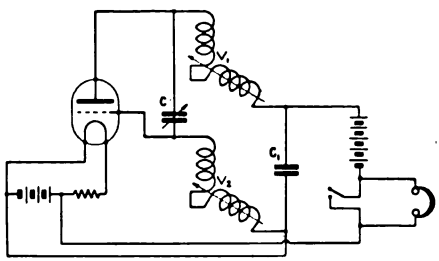

FIG. 1.

The variometers and the variable condenser are all simultaneously variable, one coil of each variometer being fixed to and rotated with the moving plate system of the condenser, and the other two coils secured to the fixed plate system. By this method a greater wavelength range is obtained in the one scale, with the added advantage of a straight line law connecting wavelength and angular movement of scale.

In order to open out the wavelength scale the range of the variable condenser is altered by a three position switch by connecting its two insulated sections either in series or in parallel or by using one section alone.

Single Valve Amplifying Receiver for extra wide wavelength range (600 to 20,000 metres).—The set, of which Fig. 2 is an exterior view, is completely self contained, the aerial and earth leads being brought direct to it. The only apparatus required external to the set are the 4-volt accumulators, 50-volt anode dry battery and a pair of high resistance telephones.

Single circuit tuning is employed, the inductance being a continuously variable multi-coil variometer, Fig. 3, in which an exceedingly high range of mutual inductance variation is obtained. The coils of the variometer are very flat and are embedded in insulating discs, one of which D_1, may be

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rotated between the other two D_2 and D_3. This arrangement gives an evenness of scale throughout the whole 180° of movement.

An inductance range of 3,500 to 50,000 microhenrys is obtained on the long wavelength scale, whilst a two position multi-functioning switch S alters the internal variometer connections to obtain a short wavelength inductance range of 200 to 3,500 microhenrys. An inductance ratio of 250 to 1 is thus obtained throughout the range of the instrument.

FIG. 2.—Single Valve Amplifying Receiver (*H. W. Sullivan*).

The variometer is used in conjunction with an adjustable bank of fixed condensers which may be placed either in series or in parallel with the variometer by means of a series-parallel switch giving the wavelength range stated above.

The variometer is also fitted with a set of reaction windings which are embedded in the disc D_4 and rotated relative to the main inductance on a spindle concentric with the spindle of the latter, the two operating handles H_1 and H_2 being conveniently placed one above the other.

The mutual inductance between the variometer coils and the reaction coils (the latter being also changed by the long-short wave switch S may be

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adjusted to such values as will produce self-oscillation of any frequency corresponding to wavelengths between 600 and 20,000 metres.

The whole of the moving system is supported in upper and lower bearings carried by a framework F of rigid construction, which also supports the fixed system. Connection is made to all moving units through contact rings and fingers C.

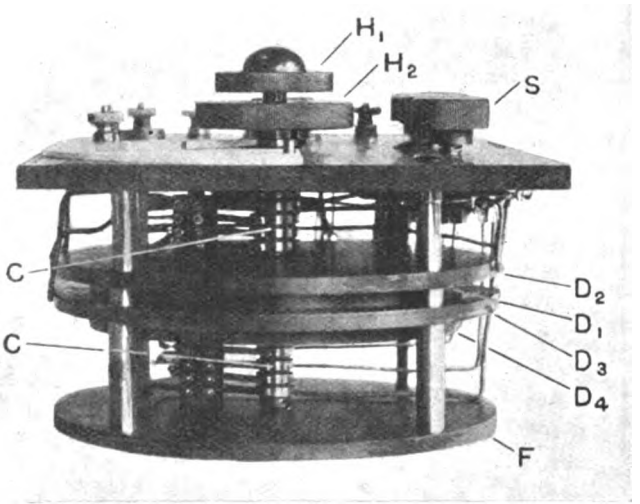

FIG. 3.– Long-range Variometer, Interior View (*H. W. Sullivan*).

Standard Experimental Valve Amplifying Receiver Panel.—On this panel a selected group of standard components has been arranged with a view to making possible the greatest number of variations of circuits using one, two, three, or more valves.

A Three Valve Amplifying Receiver having loose coupled tuning circuits, and reactance-capacity intervalve coupling.

Selenium Amplifier.—In this arrangement due to K. C. Cox a sectional selenium cell is acted upon by the light beam reflected from the receiving galvanometer, when the apparatus is employed for cable reception. The selenium sections are arranged as a series of bridge arms, and the received signals thus cause correspondingly large current changes in the selenium bridge circuit, in which circuit is placed the local receiving instrument or relay. By a suitable addition of other apparatus, this instrument could evidently be adapted to other uses, in which amplification of telegraphic signals is required.

Standard fixed and variable condensers, high frequency apparatus for laboratory measurements, etc., were also shown,

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THE ZENITH MANUFACTURING COMPANY showed a number of regulating resistances, potentiometers, etc., suitable for use in conjunction with wireless apparatus, as well as for other purposes.

THE DUBILIER CONDENSER COMPANY had on exhibition samples of various types of condensers suitable for wireless telegraphy and telephony, as well as for power-line protection and other purposes.

MESSRS. CREED & CO., LTD., exhibited their high speed receiving perforator and printer, and gave demonstrations of its application to the reception and recording of wireless messages. This apparatus has already been briefly described in these columns (see pp. 37–38, January, 1921, issue) where some samples of the tapes were also reproduced.

THE MARCONI-OSRAM VALVE CO., LTD., showed receiving, amplifying, and rectifying valves of the latest types, and in various sizes, including a number of valves with a new type of filament exhibited by the research laboratories of the General Electric Co., Ltd., London. The filament of these valves runs at a very much lower temperature than the ordinary tungsten filament in the types of valves in general use.

The advantages so gained are of considerable importance. In the first place the life of the valve is much longer since at the lower temperature there is little or no disintegration of the tungsten. Secondly, the watts required to heat the filament are reduced to about one-sixth of the usual values for filaments of the same size. The advantage does not end here, however, for the increased strength resulting from lower temperature permits the use of finer filaments, the watts for heating these being only about one-twentieth to one-fortieth of usual valves. Thus it is possible to work a six-valve amplifier with a current consumption of half an ampere from a single accumulator cell.

The vacuum in these valves is uniformly high and their characteristic curves are very similar to those of existing types for use in wireless telegraphy, but in one respect there is a marked improvement. Owing, apparently, to a change in the "contact potential" between the filament and grid there is a reduction (in the proportion of at least 10 to 1) in the current in the grid circuit when the grid is in conducting connection with the negative end of the filament. In consequence the application of a negative priming voltage to the grid to reduce the energy expenditure in the input circuit becomes in many cases no longer necessary.

With these valves the spontaneous "crackling" noises in sets of high amplifying power due to sudden changes in the internal action of the earlier valves of the cascade are absent, a result which with the ordinary tungsten filament can be achieved only by very careful selection of the filament metal.

The valves shown represented standardised types not isolated specimens; the work of developing the processes of preparation was carried out by Mr. M. Thompson of the laboratory staff.

(*To be continued.*)

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Notes.

Personal.

The Liebman Memorial Prize has been awarded by the Institute of Radio Engineers to R. A. Weagant for his work on the elimination of the effects of atmospheric disturbances in radio communication. [1822]

The editor of the RADIO REVIEW, Professor G. W. O. Howe, is resigning his position at the City and Guilds Engineering College, South Kensington, on his appointment to the National Physical Laboratory, where he will take charge of the electrical standards and general electrical measurements, including wireless and high frequency work. [1929]

The death is announced of Dr. F. Dolezalek on December 10th at the age of forty-eight. In 1907 he succeeded Rubens as Professor of Physics at Berlin, where he afterwards founded and directed the Institute for Physical and Electrical Chemistry. [1877]

We regret to announce the death on December 13th last of Dr. Alexander Muirhead at the age of seventy-two. Dr. Muirhead, as is well known, was associated with Sir Oliver Lodge in the latter's early work in connection with wireless telegraphy. [1964]

Commercial.

A NEW WIRELESS STATION AT NORTHOLT.—We have received some interesting details of a new wireless station which is being erected by the Post Office at Northolt, which is quite close to London and lies half-way between Uxbridge and Harrow.

The aerial system will consist of a triangular network each side of which will be 650 feet in length, and the aerial will be supported by three Elwell wooden lattice towers each 446 feet in height. The earth system will consist of a network of copper strip connected to metal plates buried at the bottom of the excavations made to receive the stay wire anchorages and tower and building foundations. The transmitting equipment, both primary and secondary, will be Elwell-Poulsen arc generators fitted with remote control. It is interesting to note that alternative tenders were obtained for arcs, valves and alternators and it was decided to instal the arc immediately. In the near future a valve set employing the very latest practice in valves, viz., the high-power silica valve, will also be installed. And when this has been done comparative tests will be made to ascertain which system is the more economical and reliable in commercial operation.

The specification calls for a minimum output of 50 amperes in the aerial, and arrangements are being made for the emission of a single wave when transmitting, and the complete suppression of radiation when spacing, instead of the usual de-tuning.

We believe that this will be the first arc station of any size to operate commercially on this principle. It is unnecessary to state at length the many advantages gained by being able to stop radiating when spacing, such as the saving in power, and the freedom from jamming which will result. Although the output to the aerial is quite considerable, the station will be operated directly from the Central Telegraph Office, London, at speeds of about sixty words per minute, but provision has been made for the installation of high-speed signalling at more than 100 words per minute.

The whole of the wireless equipment and masts have been placed in the hands of Mr. C. F. Elwell, who is at present also completing the two imperial wireless stations at Oxford, and at Cairo.

The object of the new station is to give direct working to Central Europe, and the rates per word will be the same as the existing telegraph rates. The service should be vastly superior, however, as the use of lines passing through many different foreign countries will be eliminated. [1977]

A NEW VALVE COMPANY.—A new company has been formed under the name of the Mullard Radio Valve Co., Ltd., for the manufacture of radio valves and apparatus. The directors are Sir Ralph Ashton (chairman), B. Binyon of the Radio Communication Co., Ltd., C. F. Elwell, whose name is associated with the development of the Poulsen arc, and S. R. Mullard (Managing Director). Mr. Mullard's name first came before the public as the inventor of

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the "Pointolite" lamp, but to wireless men he is known chiefly as the inventor of the carbonised cellulose grid leak and anode resistance and as a maker of both small and large thermionic valves. [1922]

WIRELESS TELEPHONY AT AMSTERDAM EXCHANGE.—Communication between Amsterdam Telephone Exchange and the provincial exchanges is to be maintained by wireless telephony. [1926]

WIRELESS STATIONS IN MEXICO.—The Mexican Minister for Public Works has called for tenders for four wireless stations, two of which are to be situated at Manzanillo and Morelio Platz. The Mexican Government estimate amounts to three million dollars. [1927]

A NEW TRANSATLANTIC STATION.—It has been announced that a new transatlantic station is being erected by a French firm at Banjica near Belgrade. It is to operate on the Marconi system. [1979]

PUBLIC WIRELESS SERVICE TO FRANCE.—A new public telegraph service between England and France was opened on Saturday morning, January 8th, 1921. High-speed duplex wireless transmission is employed, and it is hoped that the additional means of communication between England and the Continent will afford considerable relief to the present congestion. The service will be conducted by Marconi's Wireless Telegraph Co., Ltd., and the Compagnie Générale de Télégraphie sans Fil, these companies operating under licences from the British and French Governments. The current telegraph rates between the two countries will apply. For this service the latest high-speed automatic apparatus such as was used so successfully between Geneva and London during the sitting of the Assembly of the League of Nations will be employed. [1914]

NEW BELGIAN WIRELESS STATION.—The *Libre Belgique* announces that the Department of Railways will shortly begin in Belgium the construction of a powerful wireless station which will be capable of transmitting messages to North and South America and to the Congo. [1915]

ANOTHER BIG WIRELESS STATION FOR FRANCE.—The foundation of the largest wireless station in the world was laid on Sunday, January 9th, at Saint Port near Melun, by M. Deschamps, Under-Secretary for the French Posts and Telegraphs. The work of construction will take at least two years. [1916]

The Union Government of South Africa has acquired the radio station at Windhuk which was erected by the Germans. It is to be re-equipped for communication with England *via* Cairo. [1723]

General.

At a joint meeting of the Institute of Radio Engineers, New York, and of the New York Electrical Society on November 10th last, Dr. E. F. W. Alexanderson outlined some of the constructional features of the high-power radio station which is to be built on Long Island by the Radio Corporation of America. Alexanderson high-frequency alternators are to be installed and in the discussion of the paper considerable interest was expressed in the multiple antenna arrangements which have been developed by Dr. Alexanderson. [1823]

A NEW WIRELESS JOURNAL.—We have received the first number of the *Journal of the Dutch Radio Society*. Its contents consist of a list of officers and members of the society and the paper by Dr. van der Pol on the amplitude of the oscillations in triode-generator circuits which was published in the November and December (1920) numbers of the RADIO REVIEW. [1947]

In connection with the air mail service between San Francisco, Salt Lake and Cheyenne, U.S.A., lamps have been fitted to the aeroplanes and connected to the radio apparatus so that the lamps light up when the planes are within a certain path about 200 feet wide. Approach to the destination is indicated by the flashing of the lamps. [1789]

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Review of Radio Literature.

1. Abstracts of Articles and Patents.

Radio Stations and Installations (General and Descriptive Articles).

1423. **L. Chaulard.** The Lafayette Wireless Station at Croix d'Hins. (*Annales des Postes, Télégraphes et Téléphones*, 9, pp. 504—515, December, 1920.)
See pp. 85—93 in this issue for abstract.

1424. **Cabanne.** The Lafayette Radiotelegraph Station. (*Génie Civil*, 77, pp. 473—482, December 11th, 1920.)
See pp. 85—93 in this issue.

1425. The Lafayette Radiotelegraphic Station. (*Radioélectricité*, 1, pp. 78—81, July, 1920. *L'Elettrotecnica*, 7, pp. 567—568, November 5th, 1920—Abstract.)
See pp. 85—93 in this issue for abstract.

1426. **R. Roscher.** The High-power Radio Station at Kamina (Togo). (*Archiv für Post und Telegraphie*, pp. 241—266, August, 1920.)
See p. 68 in this issue for abstract.

1427. Marconi's Wireless Telephone. (*Scientific American*, 123, p. 207, August 28th, 1920.)
Gives details of a 15 kW apparatus.*

1428. Which System for Long-distance Communication? (*Radio Nieuws*, 3, pp. 219—223, August, 1920.)
A comparison of the various systems.

1429. **H. S. Pyle.** An Oriental Radio Set. (*Wireless Age*, 7, pp. 18—20, May, 1920.)
A description with illustrations is given of a radio installation on the Japanese vessel *Tosida Maru III.*

1430. Wireless Telegraphy in Submarines. (*Produccion*, 11, April 15th, 1920.)
A short account of work done in France and America on the installation of wireless receiving apparatus on submarines to enable reception and transmission to take place when submerged.†

1431. **G. W. O. Howe.** The Generation of Large Powers at Radio Frequencies. (*Chemical News*, 121, p. 63, August 6th, 1920.)
See RADIO REVIEW, 1, pp. 490—491, July, 1920.

1432. **F. H. Newman.** Thermionic Valve in Wireless Telegraphy. (*Beama Journal*, 7, p. 381, November, 1920.)
The uses of thermionic valve apparatus as detector, amplifier and oscillation generator are discussed.

Static or Transformer Frequency Raisers.

1433. **T. Kujirai.** Researches on Frequency Transformers. (*Journal of the College of Engineering*, Tokyo, 10, pp. 37—143, March 30th, 1920. *Journal of the Engineering Institute of Canada*, 3, Engineering Index p. 194, September, 1920—Abstract.)
The results of theoretical and experimental investigations on frequency changers are given. For a given flux density and current density the volt-ampere capacity of static frequency transformers is found to be a maximum when the copper space is equal to five-fourths of the iron space and under these conditions the maximum efficiency occurs when the iron loss per unit volume is equal to the copper loss per unit volume.

1434. **Marconi's Wireless Telegraph Company, Limited.** Frequency Changer. (*French Patent* 503084, November 15th, 1916. Published June 2nd, 1920.)
An alternator is connected to the primary of a closed core transformer so as to produce a

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* See also RADIO REVIEW Abstracts Nos. 900 and 901, October, 1920.

† See also RADIO REVIEW Abstract No. 85, December, 1919.

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rotating field and the magnetisation of the core is carried towards the saturation point. Secondaries which have a constant phase-difference are connected to the high-frequency mains, so as to establish a high-frequency current in them. For further particulars, see *British Patent* 14423/1915.

1435. **Compagnie Générale de Radio-Télégraphie.** Frequency Transformer. (*French Patent* 502202, May 8th, 1915. Published May 7th, 1920.)

A static frequency transformer has a number of shunt circuits which include inductances having different magnetic properties, acting on an unsaturated magnetic circuit which combines the fluxes produced by the currents in the shunts, whereby the resulting flux has a frequency which is a multiple of the primary frequency.

1436. **J. Zenneck.** A Contribution to the Theory of Magnetic Frequency Changers. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 468—491, December, 1920.)

A quantitative discussion of the well-known magnetic frequency doublers and triplers in which iron-cored one-to-one transformers, with (or without) supplementary D.C. excitation, are used. The relation $B = \varepsilon H - \varepsilon' H^3$ is assumed, where B is the magnetic induction, H the magnetic field and ε and ε' are constants.

A further assumption made is that the current harmonics are small compared to that of the fundamental. The derived formulæ are modified to allow for the effect of the hysteresis of the iron.

1437. **F. C. Ryan.** The Status of the Static Frequency Doubler in Radio Engineering Practice. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 509—524, December, 1920.)

Continuous wave generators are discussed under the following heads: (*a*) direct current arc oscillator, (*b*) power electron tube, (*c*) radio frequency alternators. The principles underlying the working of the Goldschmidt type of alternator, which is a combined generator and frequency-multiplying device, are investigated in detail. Mathematical expressions for the secondary voltages of the unloaded doubler of the polarised core type are derived, based on the empirical relation $B = A \tan^{-1} ax + Cx$ where B is the magnetic induction, x ampere-turns per centimetre length of magnetic circuit and A, C and a constants.

Alternators of the type considered (*i.e.*, medium frequency) can be operated in parallel, while if increased frequency is required two doubling stages may be introduced. Small frequency changes are obtainable through variation of alternator speed and larger steps by more or fewer doubling stages. Various methods of modulating the radio frequency energy are also discussed.

Thermionic Valves, Theory, etc.

1438. **Research Staff of the General Electric Company, London.** The Disappearance of Gas in the Electric Discharge. (*Philosophical Magazine*, 40, pp. 585—611, November, 1920.)

This research conducted by N. R. Campbell and J. W. Ryde is an attempt to determine the cause of the disappearance of gas under the electric discharge at low pressure, the discharge being in the form of electronic emission from an incandescent tungsten filament. Preliminary observations showed that the disappearance of gas was closely connected with the appearance of the glow in the containing vessel. The electrical conditions in which the glow appears are described briefly. It usually appears sharply at a definite P.D. between the electrodes called the glow potential. Observations are described on the relations between glow potential and (1) thermionic emission; (2) the pressure of the gas; (3) the nature of the gas; and (4) the form of the electrodes. The importance of the glow potential for determining the rate of disappearance of gas is pointed out.

1439. **F. Horton and Miss D. Bailey.** The Effect of a Trace of Impurity on the Measurement of the Ionisation Velocity for Electrons in Helium. (*Philosophical Magazine*, 40, pp. 440—450, October, 1920.)

1440. **G. Stead and B. S. Gossling.** On the Relative Ionisation Potentials of Gases as observed in Thermionic Valves. (*Philosophical Magazine*, 40, pp. 413—425, October, 1920.)

For determining potential differences necessary to cause positive ions to be produced in soft thermionic valves, the plate current—plate voltage characteristics are plotted. The occurrence of ionisation is indicated by a departure from the three-halves law for these

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characteristics. The deviations are most easily shown by plotting the characteristics on logarithmic co-ordinates. The method has been applied to six different gases giving the following results for the ionisation potentials in volts :—Mercury vapour 10·8; Argon 12·5; Hydrogen 15; Carbon monoxide 15; Nitrogen 17·2 and Helium 20·8. Reference is also made to the method described elsewhere in this REVIEW,* with which similar values were obtained. (See also pp. 75—77 in this issue.)

1441. **C. J. Fitch.** The Vacuum Tube as a Frequency Multiplier. (*Wireless Age*, 7, pp. 29—30, March, 1920.)
An arrangement is described for frequency trebling using three-electrode valves on the lower bend on their characteristics.

Radio Receiving Apparatus.

1442. **Société des Établissements Gaumont.** Receiving Apparatus. (*French Patent* 503240, March 8th, 1917. Published June 5th, 1920.)
The invention relates to an apparatus for recording the variations produced in an electric circuit. The apparatus comprises an electromagnet connected in the circuit in the field of which is disposed a vibrating plate carrying a pen or stylo which records the vibrations of the plate by impressing them more or less deeply on a suitable surface.

1443. New Development in Wireless Telegraphy. (*Elektrotechnische Zeitschrift*, 41, p. 898, November 11th, 1920.)
A vague reference to a Danish invention of **Rahbek** and **Johnsen** being developed by **Huth & Co.** of Berlin, of which further particulars are promised at a future date. It is apparently a relay depending on the variable mechanical force between a rotating cylinder of lime or stone and a conductor, when current passes between them.

1444. **L. B. Salt.** A Sectional Receiving Set. (*Wireless Age*, 7, pp. 38—41, June, 1920.)
Illustrations are given of parts of the set.

1445. **F. R. Pray.** A Sensitive Portable Receptor. (*Wireless Age*, 7, pp. 26—27, July, 1920.)
An illustrated description.

1446. **N. A. Nyquist.** Portable Receiver. (*Wireless Age*, 7, pp. 27—29, July, 1920.)
An illustrated description.

1447. **C. T. Jacobs.** A Universal Range Portable Receiver. (*Wireless Age*, 7, pp. 31—36, July, 1920.)
Constructional details with working drawings are given.

1448. **R. J. McAusland.** What the Amateur can Learn from the Navy. (*Wireless Age*, 7, pp. 13—15, June, 1920.)
The radio receiver type C.M.294C built by the American Marconi Company for the U.S. Navy is described and illustrated together with wiring diagrams.

1449. **R. A. Weagant.** Improved Connections for Two Element Vacuum Tubes. (*Wireless Age*, 8, p. 21, October, 1920.)
In the two-electrode valve receiver described in this article the filament connection is made to a special tapping brought out from the centre of the filament. It is claimed that this arrangement gives greatly increased strength of signals.

1450. **R. Evans.** Wireless Reception with the Electronic Valve. (*Sea, Land and Air*, 3, pp. 478—482, October, 1920.)
Deals briefly with various forms of valve receiving circuits.

1451. Regenerative Receiver and Vacuum Tube Units. (*Electrical World*, 76, p. 1001, November 13th, 1920.)
A short note illustrating a regenerative receiver type C.R.34 manufactured by A. H. Grebe & Co., New York.

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* RADIO REVIEW, 1, pp. 525—531, August, 1920.

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1452. **E. T. Jones.** Audion Circuits. (*Wireless Age*, 8, p. 27, October, 1920.)
An arrangement is described by means of which it is possible to rapidly change over a given receiving circuit with single valve to operate in a number of different ways, as detector, amplifier, or regenerative receiver.

1453. **R. N. Jones.** Direct Coupled Radio Receiving Sets. (*Wireless Age*, 8, p. 28, October, 1920.)
A number of arrangements of a single valve direct-coupled receiver are described.

1454. **J. C. Morris.** A Successful Undamped Wave Circuit. (*Wireless Age*, 7, pp. 27—28, March, 1920.)
A valve receiver with regenerative coupling is described.

1455. **A. B. Ballhatchet.** Some Valve Circuits. (*Model Engineer*, 43, pp. 323—327, October 21st, 1920.)

1456. **P. Maurer.** The Reception of Undamped Waves. (*L'Électricien*, 51, pp. 413—415, October 1st, 1920.)
A general article including some constructional details.

Amplifiers.

1457. **M. Latour.** Valve Amplifier. (*French Patent* 503941, December 12th, 1917. Published June 21st, 1920.)
The invention relates to amplifiers of the multi-stage kind and more particularly for low frequency. Two arrangements of valve tubes are shown.

1458. **L. N. Brillouin.** Receiving Apparatus. (*French Patent* 503766, October 8th, 1917. Published June 17th, 1920.)
The invention relates to telephone receiving apparatus for wireless telegraphy employing a series of thermionic valves. For further particulars see *British Patent* 131055.*

1459. **Dr. Kooman's** Note Amplifier. (*Radio Nieuws*, 3, pp. 231—239, August, 1920.)

1460. **H. W. Lewis.** Regenerative Receiver *versus* Cascade Amplifier. (*Wireless Age*, 7, pp. 20—22, February, 1920.)
A critical discussion of the relative merits of these two receivers. A conclusion is reached in favour of the cascade amplifier particularly for short wavelengths.

1461. **A. H. Kluze.** A Two-stage Amplifier Cabinet. (*Wireless Age*, 7, pp. 28—29, June, 1920.)
An inductively coupled amplifier is described.

1462. **L. N. Brillouin.** Receiving Apparatus. (*French Patent* 503765, October 8th, 1917. Published June 17th, 1920.)
The invention relates to telephone receiving apparatus for wireless telegraphy employing a series of thermionic valves. For further particulars see *British Patent* 131054.*

Subsidiary Radio Apparatus (including Protective Apparatus, etc.).

1463. **M. Latour.** Valve Amplifier. (*French Patent* 502360, December 12th, 1918. Published May 12th, 1920.)
The invention relates to the excitation of vacuum tube amplifiers by means of a continuous current machine having two windings of high and low voltage respectively.

1464. **J. Bethenod.** Aircraft Wireless Apparatus. (*French Patent* 502670, December 18th, 1915. Published May 22nd, 1920.)
An installation for flying machines has the parts enclosed in a casing of a shape having a minimum resistance to flight through the air. The parts comprise an alternating current magneto and a rotating spark gap, driven by a propeller.

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* RADIO REVIEW Abstract No. 305, April, 1920.

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1465. **F. Brocq and H. Olivier.** Aircraft Wireless Apparatus. (*French Patent* 502678, January 10th, 1916. Published May 22nd, 1920.)
The specification describes an alternating current generator for use in wireless telegraphy on a flying machine. The armature is fixed and carries polar projections and magnetising windings. The inductor is formed of permanent magnets mounted alternately of opposite polarity on the hub of the motor spindle. A form of spark gap is also described.

1466. **O. C. Cote.** A Remote Control Antenna Switch. (*Wireless Age*, 7, pp. 24—26, April, 1920.)
Constructional details with dimensioned working drawings of the switch are given.

1467. **M. P. Koopman.** A 1 kW Antenna Switch. (*Wireless Age*, 7, pp. 26—27, April, 1920.)
Constructional details are given with this article.

1468. **G. W. Benson.** An Original Antenna Switch. (*Wireless Age*, 7, pp. 23—24, April, 1920.)
Constructional details are given.

1469. **F. McGulst.** An Antenna Switch. (*Wireless Age*, 7, p. 28, May, 1920.)

1470. **J. Bethenod and E. Girardeau.** Transmitting and Receiving Apparatus. (*French Patent* 502280, June 3rd, 1915. Published May 8th, 1920.)
The invention relates to radiotelegraphic stations in which the antenna is excited indirectly, and it has for its object to permit the connection of the receiving circuit or the transmitting circuit by the operation of a single device, while at the same time obtaining an automatic protection against incorrect movements. For this purpose, there is arranged in the excitation circuit of the alternator a switch which varies the excitation of the alternator when the receiving or transmitting apparatus is connected to the antenna.

1471. **M. Wien.** Telephone Receiver and Ear Sensibility. (*Annalen der Physik*, 62, pp. 759—762, August 20th, 1920.)
W. Hahnemann and H. Hecht have found that the minimum audible power at a frequency of 1,000 is $1{\cdot}9.10^{-17}$ watts whereas Wien had found 16.10^{-19} watts. The former criticise the latter's experimental arrangements, but Wien points out that whereas they take the whole power striking the ear (11 cm^2), he took that striking the drum only ($\frac{1}{3}$ cm^2), this brings the difference within the range of experimental error.

1472. A High Voltage Mercury Vapour Rectifier. (*L'Elettrotecnica*, 7, pp. 454—457, September 5th, 1920; pp. 498—502, September 25th, 1920, and pp. 541—546, October 25th, 1920.)
A description of various types of mercury vapour rectifying apparatus and of its mode of action.

1473. **J. A. Weaver.** Combined Kick-back Preventer and Switch Panel for Experimental Radio Stations. (*Wireless Age*, 7, pp. 18—20, February, 1920.)
A switchboard panel is described with radio frequency protection for the supply circuit in the form of a 5,000 ohm resistance joined across the line.

1474. **T. Spooner.** High Frequency Iron Losses. (*Journal of the American Institute of Electrical Engineers*, 39, p. 808, September, 1920. *Electrical World*, 76, p. 745, October 9th, 1920—Abstract. *Revue de l'Ingénieur et Index Technique*, 27, p. 255, November, 1920—Abstract. *Science Abstracts*, 23B, p. 474, Abstract No. 894, October 31st, 1920—Abstract.)

1475. **C. Beaudouin.** Continuous Wave Transmitter. (*French Patent* 503937, December 5th, 1917. Published June 21st, 1920.)
A make and break apparatus for the production of electrical breaks of musical frequency, applicable particularly to wireless telegraphy, is characterised by the fact that the two circuits of the vibrator are electrically completely independent of one another, and that the breaks are produced by a vibrating plate which is vibrated continuously by means of an electromagnet.

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Wave Transmission (Theory, Range Tests, Upper Atmosphere, etc.).

1476. **J. Wallot.** The Definition of Wave Velocity. (*Annalen der Physik*, 62, pp. 569—572, July 16th, 1920. *Science Abstracts*, 23B, p. 656, Abstract No. 1644, December 30th, 1920—Abstract.)
A discussion of individual wave velocity, group velocity and phase velocity.

1477. **A. Sommerfeld.** The Transmission of Waves in Radiotelegraphy. (*Annalen der Physik*, 62, pp. 95—96, May 20th, 1920.) And **H. Weyl.** (*Loc. cit.*, 62, pp. 482—484, July 8th, 1920.)
A discussion of Weyl's criticism of his division of the transmitted energy into space waves and surface waves, and Weyl's reply thereto.

1478. **J. J. Thomson.** On some Optical Effects including Refraction and Rotation of the Plane of Polarisation due to the Scattering of Light by Electrons. (*Philosophical Magazine*, 40, pp. 713—734, December, 1920.)
A section is included in this article devoted to the mathematical expressions for the rotation of the plane of polarisation of an electromagnetic wave by electrons under the influence of a magnetic field.*

1479. **G. Vallauri.** Measurement of Radiation of Radiotelegraphic Aerials. (See pp. 77—85 in this issue.)

1480. **T. L. Eckersley.** The Effect of the Heaviside Layer on the Apparent Direction of Electromagnetic Waves. (See pp. 60—65 in this issue.)

Atmospherics.

1481. **C. N. Keyser.** Detection of Storms and their Travel by Radio Equipment. (*Monthly Weather Review*, 48, pp. 263—264, May, 1920.)
Indicates the importance of observations of atmospherics for meteorological forecasting and points to the need for more accurate directional measurements of storms.

1482. **Marconi's Wireless Telegraph Company, Limited.** Eliminating Atmospheric Disturbances. (*French Patent* 503241, March 9th, 1917. Published June 5th, 1920.)
In a wireless system in which a vacuum tube operates as a current-limiting device, the action of atmospherics on the receiver is eliminated by applying a variable potential difference between the cathode and the grid of the valve. In one example, the aerial is coupled to the receiver through an inductance shunted by a capacity and connected across the anode and the grid of the valve. The potential-difference between the grid and the cathode of the valve is varied by a potentiometer. For further particulars of the invention, see *British Patent* 102822.

1483. **Marconi Wireless Telegraph Company of America.** Eliminating Atmospheric Disturbances. (*French Patent* 503024, August 25th, 1919. Published June 1st, 1920.)
The specification describes a method of reducing static interference. See also *British Patent* 138588.†

Interference and Interference Prevention.

1484. **J. Bethenod and E. Girardeau.** Transmitter. (*French Patent* 502721, February 12th, 1916. Published May 25th, 1920. *Annales des Postes, Télégraphes et Téléphones*, 9, p. 483, September, 1920—Abstract.)
This specification describes means for mixing up or jambing radio communications of neighbouring stations. The length of the emitted wave and the speed of emission is varied simultaneously. The arrangement comprises wave generating apparatus and automatic controlling means to obtain a continuous variation in the wavelength, comprising inductances

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* Compare address by Dr. W. H. Eccles on p. 35 of the January, 1921, issue.
† RADIO REVIEW Abstract No. 997, October, 1920.

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and a switch for connecting the varying inductances in circuit, the switch acting at the same time on the spark gap apparatus.

1485. Some Results obtained by the Use of Filters. (*Annales des Postes, Télégraphes et Téléphones*, 9, pp. 343—346, June, 1920.)
An oscillographic investigation.

1486. **O. Scheller and C. Lorenz.** Wireless Receiving Circuit. (*German Patent* 298475, September 22nd, 1914. Patent granted October 9th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 154, August, 1920—Abstract.)
A circuit for the prevention of interference in which two or several circuits are so coupled that for long wave reception the efficient coupling for short waves is looser while for short wave reception the effective coupling for higher wavelengths is less effective.

1487. **H. J. J. M. R. de Bellescize.** Receiving Apparatus. (*French Patent* 501196, November 25th, 1918. Published April 6th, 1920.)
To increase the ease of selection the receiving circuit including the antennæ is enclosed in a Faraday cage forming an imperfect screen.*

1488. **H. W. Nicholls.** A Secret Radiophone. (*Wireless Age*, 7, pp. 23—24, March, 1920.)
In order to render the telephonic message unintelligible during its transmission between the two radio stations the modulating currents are caused to affect a telegraphone arrangement from which they are passed to the modulating valve and amplifying arrangement of the radio transmitter. The modulating impulses are stored up in the telegraphone wire and reproduced from that by means of another magnet which is mounted upon a cam mechanism so that it is in continuous motion relative to the recording magnet. The impulses picked up by this electromagnet pass from it to the modulating valve so that the waves radiated are modulated by the speech currents distorted by the moving magnet. At the receiver a similar telegraphone is employed with the recording magnet moved by the cam mechanism in synchronism with the magnet at the transmitting station. The received impulses may thus be restored to their original form before their reception in the telephones.

Duplex and Multiplex Radio Communication.

1489. **F. M. Ryan, J. R. Tolmie and R. O. Bach.** Multiplex Radiotelegraphy and Telephony. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 451—467, December, 1920.)
A critical discussion of the various systems of multiplex working seems to show that the most simple and practical method is that in which several radio frequencies are employed, selectivity being obtained by radio frequency tuning. In order to use the same antenna circuit in such a case it is necessary to use certain types of impedance networks in series with the antenna so that the reactance of the latter may be zero for the particular frequencies used. Fig. 1 shows the simplest application of this method, the antenna and loop circuits being coupled by means of the common inductance L_1'. The two radio frequency sources are loosely coupled to the antenna by means of the coils P_1 and P_2.

Tests of the practicability of such a method have been carried out over a distance of five miles, wavelengths of 1,890 metres and 2,100 metres being used. The Heising system of modulation ("constant-current" or "choke-control") was employed in the transmitter, while the receiving antenna was of the same type as that at the sending station. Practically perfect separation of communication was possible so long as the frequency difference was greater than 15,000 in the case of telephony. For satisfactory telegraphy this frequency difference could be much reduced.

By increasing the number of loops (L_1C_1) it was found possible to carry out quintuplex radiotelephony and telegraphy over the same distance.

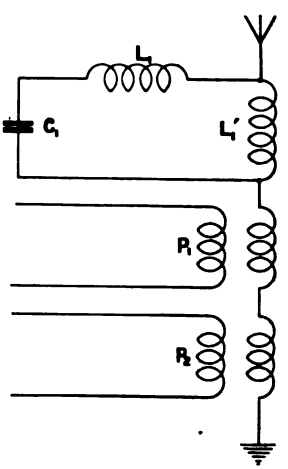

FIG. 1.

* Compare RADIO REVIEW Abstract No. 310, April, 1920.

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A mathematical investigation of the antenna system possessing zero reactance for several frequencies pointed to results in good agreement with the experimental values.

1490. Duplex Wireless System. (*Wireless Age*, 7, pp. 21—23, January, 1920. *Science Abstracts*, 23B, pp. 279—280, Abstract No. 550, May 31st, 1920.)
An abstract, with circuit diagram, of a patent by **J. Mills** and **J. R. Carson.** The aerial system is given three degrees of freedom by connecting it to earth through three independent branches, one of which is tuned to the transmitting frequency, the second to the receiving frequency and a third to a frequency differing from both the transmission and reception branches. Rejector circuits are included in each of these branches, the third branch having two rejector circuits tuned respectively to the transmitting and receiving wavelengths. The second and third branches are connected to amplifiers and detecting valves with a common telephone receiver to which they are joined in opposition. A current at the transmitting frequency will therefore flow through each of these branches but their effects will be neutralised in the receiving telephones leaving only the signal from the distant station which affects one branch only. A similar reason holds as regards the reduction of interference from atmospherics when using this circuit.

High Frequency Circuits (Theory and Measurements).

1491. **A. Press.** Theory of Antenna Radiation. (*Proceedings of the Institute of Radio Engineers*, 8, pp. 525—540, December, 1920.)
A mathematical discussion of the radiation from a finite vertical grounded antenna with a flat earth which differs from previous analyses in that the condition of the substantially sinusoidal distribution of voltage and current along the antenna is included. The derived expression for the vertical component of current density I at the receiving end is found to be of the form

$$I = \frac{a}{\sqrt{r}} \cdot \epsilon^{-\beta(r-\gamma)} \cdot \left(\frac{1}{r} - \delta\right)$$

where r is the distance between the stations and a, β, γ and δ are constants. This formula is in greater conformity with the expression suggested previously by Eccles than with the Austin-Cohen formula. The quantity $\left(\frac{1}{r} - \delta\right)$ is also suggestive of the Cohen factor $(1 + Ar)$ which was suggested to account for dispersion and diffraction.
The formulæ can be applied to the case of the horizontal antenna by considering the latter made up of two vertical antennæ combined with an image of the whole below the surface of the earth. In such a case it may be shown that "fading" of signals as a function of wavelength changes can be explained in terms of nodal spacings.

1492. **C. Breitfeld.** Skin Effect on Round Wires. (*Elektrotechnik und Machinenbau*, 38, pp. 537—543, November, 1920.)
A mathematical paper based on the assumption that Kelvin's results are not applicable at very high frequencies because of his neglect of the specific inductive capacity of copper, which the author assumes to be 9×10^{11} and thus obtains a high frequency resistance which does not increase indefinitely with increasing frequency.

1493. **R. N. Turner.** Electrostatic Coupling. (*Wireless Age*, 7, pp. 37—38, March, 1920.)
A receiving circuit is described using two variable condensers to provide an electrostatic coupling between the aerial and secondary circuits.

1494. **O. C. Roos.** An Impedance Curio. (*Wireless Age*, 7, pp. 26—29, August, 1920.)
This article discusses the question of reactive shunts.

1495. **W. Burstyn.** Coupling Phenomena with Undamped Oscillations. (*Elektrotechnische Zeitschrift*, 41, pp. 951—954, December 2nd, 1920.)
It is shown that inductive coupling can always be replaced by a branched circuit. An oscillatory circuit is first considered as coupled with an A.C. generator and then with an

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oscillatory circuit containing an A.C. generator, the apparent resistance being calculated as a function of the frequency. The case is also considered when the source is self-controlled as in a valve or arc and the phenomenon of the sudden frequency change or discontinuous resonance curve is explained.

1496. **A. Tobler.** The Use of a Valve Oscillator for the Measurement of Inductance and Capacity at the General Post Office, London. (*Journal Télégraphique*, 44, pp. 117—123, August 25th, 1920. *Science Abstracts*, 23B, p. 571, Abstract No. 1088, December 30th, 1920—Abstract.)

The application of a valve oscillating at an acoustic frequency to Wheatstone bridge measurements is described together with a rectifying arrangement for obtaining the plate voltages from an A.C. source.

1497. **C. J. Fitch.** Honeycomb Inductance Coil Mountings. (*Wireless Age*, 7, pp. 39—40, September, 1920.)

1498. **C. J. Fitch.** Wind your own Honeycomb Coils. (*Wireless Age*, 7, p. 25, June, 1920.)

1499. **M. K. Akers.** Dimensions of Inductance Coils. (*Wireless Age*, 8, pp. 20—21, October, 1920.)

The author discusses the difficulties of the design of a coil to have a given inductance. Using Lorenz's formula for calculating inductance, tables are worked out to assist in the design of coils. These tables give suitable alternative dimensions of length and diameter for different gauges of wire to give coils of various inductances.

1500. **G. de P. Foglietta.** Resistances and Inductances. (*French Patent* 504070, September 19th, 1919. Published June 24th, 1920. *British Patent* 151117, July 3rd, 1919. Patent accepted September 23rd, 1920.)

The sliding contact of a resistance or inductance for use in wireless telegraphy and wound in the form of a cylindrical coil has two curved resilient arms which bear against the wire.

1501. **T. W. Benson.** Variometers and their Construction. (*Wireless Age*, 7, pp. 23—24, February, 1920.)

An illustrated article giving constructional details.

1502. **C. Beaudouin.** Condenser. (*French Patent* 502345, November 20th, 1917. Published May 11th, 1920.)

The specification describes an electric air condenser comprising a pile of rigid laminæ of the same thickness, and of semi-circular shape, separated by carefully measured rings of the same thickness. A second similar pile of laminæ is arranged to project between the plates of the first mentioned pile, so as to vary the capacity, when one set of plates is rotated in relation to the other.

1503. **R. J. Fitzgerald.** A New Variable Condenser. (*Wireless Age*, 7, p. 19, June, 1920.)

In the vane type variable condenser described each plate is provided with enamel insulation to avoid the necessity of insulating plates between the fixed and moving vanes.

1504. **L. Bartholomew.** Further Data on Oil Dielectric Condensers. (*Wireless Age*, 8, p. 29, October, 1920.)

1505. A New Variable Condenser. (*Scientific American*, 123, p. 384, October 9th, 1920.)

An illustrated description.

1506. **M. Latour.** Condenser. (*French Patent* 493886, September 5th, 1917. Published August 23rd, 1919.)

The invention consists of a condenser of small dimensions with a shunt resistance arranged across its terminals for use in connection with valve apparatus.

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1507. **E. G. Underwood.** Construction of Variable Condensers. (*Wireless Age*, 7, pp. 26—28, February, 1920.)
An illustrated article giving dimensional details.

1508. **E. Lübeke.** The Use of Interrupted Low Frequency A.C. for Telephonic Measurements. (*Zeitschrift für technische Physik*, 1, pp. 227—230, October, 1920.)
Instead of attempting to listen to the fifty-cycle telephone current, a buzzer is introduced giving an interruption of say 500 to 1,000 per second. The questions of tuning and amplification in such cases are discussed and experimental results given.

1509. **R. W. Goddard.** Heterodyne Wavemeter. (*Wireless Age*, 7, pp. 15—17, February, 1920.)
Constructional details and dimensions of a portable heterodyne wavemeter.

1510. **E. Singer.** An Efficient Wavemeter. (*Wireless Age*, 7, p. 29, September, 1920.)
A description is given of the method of constructing a simple form of wavemeter.

1511. **T. W. Benson.** Decrement and Tuning. (*Wireless Age*, 7, pp. 41—42, March, 1920.)
Simple methods of measuring the decrement of radio circuits are described.

1512. **E. P. Hurley.** A Simple Wavemeter. (*Wireless Age*, 7, pp. 36—38, July, 1920.)

1513. **A. H. Rice.** Construction of a Simple Wavemeter. (*Wireless Age*, 7, p. 24, June, 1920.)

1514. **F. C. Boekman.** The Design and Construction of a Simple Wavemeter—Range 150—300 Metres. (*Wireless Age*, 7, pp. 29—32, June, 1920.)

1515. **O. C. Cote.** A Simple Wavemeter. (*Wireless Age*, 7, pp. 32—34, June, 1920.)
Dimensions are given with an illustration of the completed instrument.

1516. **E. S. Herrick.** The Design and Construction of a Simple Wavemeter. (*Wireless Age*, 7, pp. 34—36, June, 1920.)

1517. **O. C. Roos.** Some Electrical Guides for Wavemeter Designs. (*Wireless Age*, 7, pp. 17—22, September, 1920. *Science Abstracts*, 23B, p. 581, Abstract No. 1111, December 30th, 1920—Abstract.)
The general requirements of a wavemeter are compared with those of a receiver circuit and the general design relations for the coil and condenser worked out. Some details—such as the unilateral connection of the detector, anti-capacity switches, low-capacity coils and the use of special windings are also discussed.

1518. **Trautwein.** The Electron Tube as a Measuring Instrument. (*Telegraphen- und Fernsprech-Technik*, 9, pp. 101—104, September; pp. 119—123, October, 1920.)
A discussion of the application of the triode to various electrical measurements, *e.g.*, voltmeter, form-factor meter, peak voltmeter. The accuracy obtainable is discussed and the insertion of suitable potentiometers and resistances considered with a view to improving this accuracy by modifying the characteristics.

Radio Direction Finding.

1519. **M. Dieckmann.** Wireless Telegraphy for Position Finding in Aeroplanes. (*Luftfahrt*, 26, pp. 57—59, April 1st, 1920. *Journal of the Engineering Institute of Canada*, 3, Engineering Index p. 221, October, 1920—Abstract.)

1520. **R. Mesny.** Radio Direction Changes and Variations of Audibility. (*Technical Review*, 7, p. 222, November 16th, 1920.)
See RADIO REVIEW, 1, pp. 532—540, August, 1920; pp. 591—597, September, 1920, for original paper.

1521. **L. Pungs.** Directive Wireless Telegraphy in the German Navy. (*Elektrotechnische Zeitschrift*, 41, p. 922, November 18th, 1920.)
An abstract of a general descriptive paper read before the telegraph section of the Elektrotechnischer Verein, Berlin. Some discussion by **Falkenthal** is also reported.

1522. **L. W. van Glyck.** An Indoor Loop Antenna. (*Wireless Age*, 7, p. 36, February, 1920.)
An illustrated article giving constructional details.

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High Frequency Wire Telegraphy and Telephony.

1523. **E. Fischer.** High Frequency Telephony over the Wires of a Power-distributing System. (*Elektrotechnische Zeitschrift*, 41, p. 1021, December 16th, 1920.)

Referring to an article by Jewecke (see RADIO REVIEW Abstract No. 1325, December, 1920) the writer states that he carried out similar experiments in wireless telegraphy during the war. Particulars are given but the experiments did not lead to a practical application.

1524. **K. W. Wagner.** Multiplex High Frequency Wire Telephony and Telegraphy. (*Elektrotechnische Zeitschrift*, 41, pp. 1025—1027, December 23rd, 1920.)

A paper describing the German developments which was read at the annual meeting of the Verband Deutscher Elektrotechniker at Hanover on September 25th, 1920. See also RADIO REVIEW, 1, pp. 715—716, November, 1920, and also Abstract No. 1416, January, 1921.

Miscellaneous Methods of Communication.

1525. **Arendt.** Overhearing, its Prevention, and Earth Telegraphy. (*Telegraphen- und Fernsprech-Technik*, 9, p. 141, November, 1920. *Elektrotechnische Zeitschrift*, 41, p. 1040, December 23rd, 1920—Abstract.)

A description of the German systems used during the war, one of which is, as the author remarks, practically the same as the Fullerphone.

1526. Light Telephony. (*Scientific American*, 123, p. 402, October 16th, 1920.)

Brief reference to a German method of light telephony developed during the war.

1527. **E. Devaux.** The Guiding of Ships by Wireless. (*L'Électricité*, 2, pp. 1—2, September 15th, 1920.)

This article makes reference to some experiments on the control of ships by wireless signals and describes briefly some early experiments made by the writer about 1906 in which some very good results were obtained. The special feature of the arrangement appears to have been a selector mechanism controlled by the incoming signals by means of which any one of twelve possible orders could be transmitted to the ship.

1528. **H. V. Hayes.** Submarine Signalling. (*Engineer*, 129, pp. 491—493, May 14th, 1920. *Science Abstracts*, 23B, p. 395, Abstract No. 758, August 31st, 1920. *Technical Review*, 6, p. 589, July 6th, 1920—Abstract. *Electrical World*, 76, p. 136, July 17th, 1920—Abstract.)

A summary of various methods with constructional details of the Fessenden oscillator and of various microphonic arrangements.

1529. **G. Gaulois.** New York's Radio Pilot Cable. (*Scientific American*, 123, pp. 195 and 210, August 28th, 1920. Also *Wireless Age*, 8, p. 8, October, 1920. See also *Scientific American*, 123, p. 423, October 23rd, 1920.)

Some details are given with a map of the arrangements of a recently installed leader cable in New York Harbour. The arrangement of receiving coils with valve amplifier is given with some particulars as to the constructional details of the cable and its anchorages.

In the third of the articles referred to above reference is made to a recent test of the cable in which a destroyer was successfully piloted into the harbour by its use. An illustration of the installation on the vessel is given.

Traffic Particulars (Transmission Programmes, etc.).

1530. The Meteorological Service. (*Produccion*, 11, September 15th, 1920.)

A description of the service of wireless weather reports inaugurated in Spain on March 1st, 1920.

1531. Radio Message Circles the Earth. (*Wireless Age*, 8, p. 9, October, 1920.)

The text of the first message sent out from the Lafayette Station (Bordeaux) is given together with the reply from **Mr. Daniels**, Secretary of the U.S. Navy.

1532. Wide Expansion of Transocean Wireless. (*Wireless Age*, 8, pp. 7—8, October, 1920.)

Reference is made to agreements arranged by the **Radio Corporation of America** with other countries for long distance and high speed radio traffic.

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Radio Legislation, etc.

1533. Big Companies agree on Expansion of Radio. (*Wireless Age*, 8, p. 8, October, 1920.)
Arrangements are referred to between the **American Telephone and Telegraph Company**, the **General Electric Company of America**, and the **Radio Corporation of America** for the combined use of their inventions and patents in the development of radio work. This exchange of patent licences has been encouraged by the U.S. Navy as leading in particular to a better development of long distance communications between shore and ships.

1534. Legal Restrictions and the Amateur. (*L'Elettrotecnica*, 7, p. 546, October 25th, 1920.)
A letter advocating the removal of legislation needlessly restricting the amateur in wireless telegraphy and pointing out the advantage which America gains from the work of the great army of amateur workers in radiotelegraphy.

Miscellaneous.

1535. **A. S. Eve.** Engineering and Physics. (*Journal of the Engineering Institute of Canada*, 3, pp. 527—528, November, 1920.)
Briefly refers to the difficulties of adequate education for radio research work.

1536. The Planet Mars and Interplanetary Communication. (*Produccion*, 11, pp. 149—150, March 15th, 1920.)

1537. Interplanetary Radio Signals. (*Wireless Age*, 7, pp. 11—15, March, 1920.)
A summary of a number of expressions of opinion by **G. Marconi, C. P. Steinmetz, E. Branly** and others on this subject.

1538. **S. R. Winters.** Wireless in Forest Fire Fighting. (*Wireless Age*, 8, pp. 11—12, October, 1920.)
The installations of the U.S. Forest Service are briefly described and illustrated.

1539. **L. D. Foucault.** Telephony and Metaphysics. (*L'Électricien*, 51, p. 485, November 15th, 1920.)

1540. The International Commission for Weather Telegraphy. (*Meteorological Magazine*, 55, pp. 237—240, December, 1920.)
Some further particulars are given of the conference held in London during November of which a note was published on p. 42 of our last issue. (Note No. **1846.**)

1541. **V. G. Werner** and **K. H. Warfvinge.** TELEPHONY. (*French Patent* 488316, August 21st, 1916. Published September 20th, 1918.)
This specification describes a system for corresponding by telephone with railway trains or similar vehicles in motion. The movable circuit consists of a coil L (Fig. 2) connected to a number of oscillatory circuits L_1, C_1; L_2, C_2; etc. The frequencies of these circuits are uniformly distributed according to the frequencies of the most important of the oscillations produced by speech. For further particulars see *British Patent* 101281.

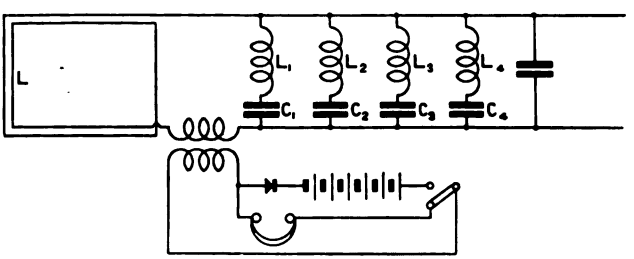

FIG. 2.

Index and Binding Cases. An announcement will be found in the advertising pages of this issue.

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2. Books.

ELECTRIC OSCILLATIONS AND ELECTRIC WAVES. By G. W. Pierce, Professor of Physics in Harvard University. (New York: *McGraw Hill Book Co., Inc.* London: *McGraw Hill Publishing Co., Ltd.* 1920. Pp. ix + 517. Price 30s. net.)

This is one of the best books we know of on this subject; it should be on the shelves of every radio engineer who is interested in the mathematical theory of his subject. It forms an excellent text-book for a course of study of the phenomena of electric oscillations. As stated on the title page it includes applications to radiotelegraphy and incidental applications to telephony and optics. No attempt is made to deal with the physics of the subject, there is hardly any mention of spark-gaps, arcs or vacuum tubes, but a thorough mathematical treatment is given of the fundamentals of the theory of electric oscillations and electric waves. The volume is divided into Book I. on Electric Oscillations and Book II. on Electric Waves; these are almost independent and can be read in either sequence provided the reader has a fair knowledge of mathematics. Book I. contains seventeen chapters and Book II. nine. The first three chapters deal with oscillations and discharges in a circuit containing inductance, capacity and resistance, then follows one on the geometry of complex quantities which is then applied to the circuit with a sinusoidal impressed E.M.F. and thus to the problem of resonance. Chapters VII. to XI. are devoted to a very complete study of two coupled oscillatory circuits. The following chapter is entitled "Resonance Relations in Radiotelegraphic Receiving Stations under the Action of Persistent Incident Waves." Chapters XIII. and XIV. deal with various methods of coupling two or three oscillatory circuits and the various phenomena involved in tuning these combinations. Forty-four pages are then devoted to a study of the detector and blocking condenser shunted across the tuning condenser of the circuit coupled to the receiving aerial. Chapter XVI. deals with a subject of growing importance, viz. artificial lines and electrical filters; this subject is treated very fully. The concluding chapter of the first book is devoted to electric waves on wires in a steady state. The second book opens with a chapter on Gauss' theorem, Poisson's equation, etc., in electrostatics and magnetostatics, followed by a chapter on Maxwell's equations. Chapter III. deals with Poynting's theorem of energy transfer and Chapter IV. with the wave equations and the simple plane wave solution. Chapter V. is devoted to the reflection of a plane wave from a perfect conductor and Chapter VI. to the reflection and refraction by a homogeneous insulator. This is followed by a study of wave propagation through an imperfectly conductive medium. The radiation of electromagnetic waves from an oscillatory doublet is then applied to the Hertzian oscillator to determine its radiation resistance and in the final chapter to the radiation characteristics of an actual antenna. This concluding chapter is a very thorough attempt to determine the radiation resistance of an antenna. In an appendix several theorems in connection with the solution of differential equations are proved.

We have noted two or three misprints, but the book is remarkably free from such blemishes and we have no hesitation in recommending it both as a text-book and as a book of reference to all those who require something more than a mere qualitative knowledge of the phenomena occurring in alternating current and especially in high-frequency circuits.

G. W. O. H.

Books Received.

TELEGRAPHY, TELEPHONY AND WIRELESS. J. Poole, Wh.Sch., A.M.I.E.E. (London: *Sir Isaac Pitman & Sons, Ltd.* Pp. 120. Price 3s. net.)

EXPERIMENTAL WIRELESS STATIONS. Philip E. Edelman, E.E. (London: *Henry Frowde and Messrs. Hodder and Stoughton.* New and Revised Edition, 1920. Pp. x + 392. Price 16s. net.)

THE ELECTRICIAN'S HANDY BOOK. A Reference Book for the Advanced Electrician, and a Text-book for the Student. T. O'Conor Sloane, A.M., E.M., Ph.D. (London: *Henry Frowde and Messrs. Hodder and Stoughton.* Fifth Edition, 1920. Pp. 823. Price £1 7s. 6d. net.)

WIRELESS DESIGN AND PRACTICE. Part I.—Transmitters and Receivers. Part II.—Practical Circuits. M. B. Sleeper. (London: *Henry Frowde and Messrs. Hodder and Stoughton.* 1920. Pp. 246. Price 7s. 6d. net.)

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THE RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

VOL. II **MARCH, 1921** NO. 3

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PHILIP R. COURSEY, B.Sc., A.M.I.E.E.

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THE
RADIO REVIEW

VOL. II MARCH, 1921 NO. 3

The Effect of Impurities on the Ionisation Potentials Measured in Thermionic Valves.*

By L. S. PALMER, M.Sc.

1. Introduction.

The following work was undertaken with the object of determining the causes of the low value obtained for the ionisation potential of helium by a valve method recently described in the RADIO REVIEW† by Dr. Hodgson in conjunction with the author. Since the publication of this paper Stead and Gossling‡ have, by a different valve method, obtained a similarly low value. They also obtained a value of 12·5 volts for the ionising potential of argon, which value is 4·1 volts less than that obtained by Hodgson and Palmer in the work previously mentioned.

Professor Horton and Miss Bailey§ have shown that the addition of a trace of mercury vapour to helium is sufficient to cause ionisation phenomena at voltages varying from about 20 to 25, but that true ionisation of the helium does not occur with voltages less than 25. These effects were accounted for by the fact that "20·5 volt" radiation of helium can ionise the impurities of low ionisation potential that may be present in the tube.||

This explanation is possible since ionisation of a given atom occurs when sufficient energy is absorbed to cause the removal of one or more of the constituent electrons of the atom. Ionisation can be caused by the bombardment of the atom by an electron whose energy (by virtue of its velocity) is sufficient to cause the removal of one or more electrons from the sphere of influence of the positive atomic nucleus. The ionisation potential is that difference of potential through which an electron must fall before it acquires this critical velocity.

The resonance potential is that voltage fall which will give an electron just sufficient energy to displace one of the constituent electrons of an atom from one orbit to another, but is insufficient to remove the electron completely, that is, is insufficient to cause ionisation. Bohr has pointed out that ionisation can occur if the gas atom absorbs sufficient energy from other

* Received November 3rd, and in final form November 18th, 1920.
† Hodgson and Palmer, RADIO REVIEW, 1, p. 525, August, 1920.
‡ *Philosophical Magazine*, 40, p. 413, October, 1920.
§ *Philosophical Magazine*, 40, p. 440, October, 1920.
|| Bohr, *Philosophical Magazine*, 30, p. 410, 1915.

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sources other than from a moving electron. In particular, ultra-violet light of sufficiently high a frequency may cause ionisation.

Resonance is accompanied by the emission of radiation in the form of ultra-violet light. If the energy necessary for " resonance impact " of one atom is greater than the energy necessary for the ionisation of another atom, then the resulting ultra-violet light from the first atom may cause ionisation of the second. Thus, since the resonance potential of helium is 20·5 volts, the resulting ultra-violet light will have a sufficiently high frequency to cause ionisation of (say) mercury vapour, the ionisation potential of which is only 10·5 volts. Since the resonance potential of argon is 12·5 volts which is greater than the ionisation potential of mercury, it was thought that this explanation may also account for the different values for the ionisation potential of argon quoted above.

Again Bohr has shown * that ionisation should occur more readily in the case of an atom which has already absorbed sufficient energy to cause it to resonate, that is the critical ionisation potential for unstable or resonated atoms will be less than the ionisation potential necessary for stable or normal atoms (see p. 120).

2. Method.

The method of investigation was similar to that previously used by the author and described in the paper referred to above. Three-electrode thermionic valves were employed in which the plate potential (V) was varied,

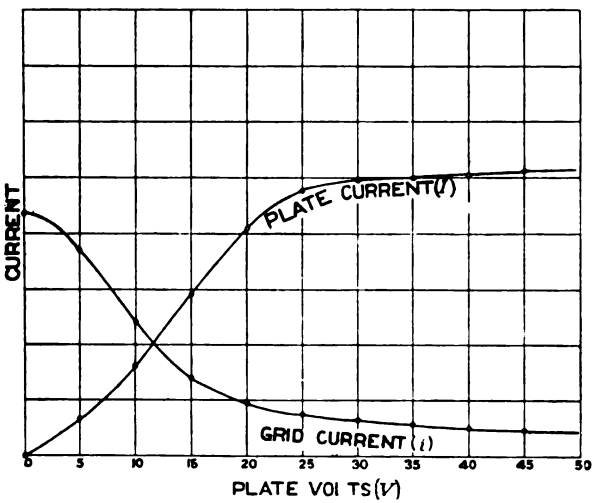

FIG. 1. Hard Valve.

in order to control the grid current (i) and the plate current (I). The grid was kept at some constant positive potential (v). The (i, V) characteristic and the (I, V) characteristic for a hard valve are shown in Fig. 1.

* *Philosophical Magazine*, 30, p. 410, 1915.

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With a soft valve the curves bend up at the points B and B′ of Fig. 2, due to the extra electrons produced by bombardment of the filament by positive ions. The corrected value of V' was taken to be the ionisation potential of the gas present in the valve. In the case of helium the value thus obtained was 21·9 volts.

There is some independent evidence, about to be published, which tends to show that the valve used also contained a trace of mercury. Assuming the bend in the (i, V) characteristic of the helium valve to be due to ionisation of the mercury vapour by the "20·5 volt" radiation of helium, it was to be expected that a further change in the slope of the characteristic would occur in the neighbourhood of 25—26 volts. This was concluded because if ionisation of the helium atom occurred by impact with an electron whose

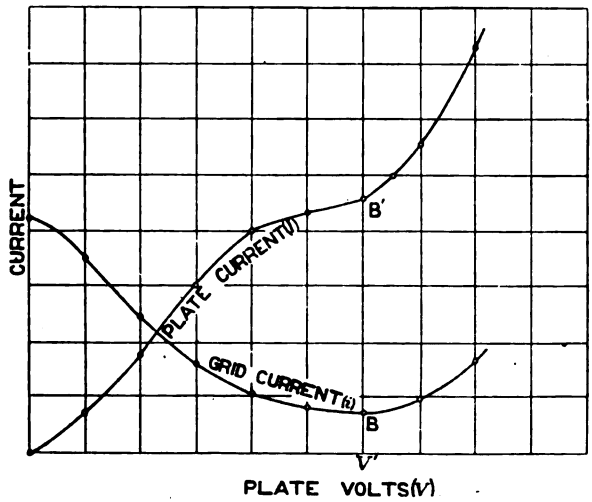

FIG. 2.—Soft Valve.

energy was that obtained by falling through a potential gradient of 25·6 volts (Horton's result) then at this value of the plate potential an increased number of electrons and positive ions would be produced by the ionisation of the helium atoms. This augmentation of the number of current carriers would increase the slope of the characteristics at the point where ionisation first set in, that is when the corrected plate potential is about 25·6. To test this the (i, V) characteristic was obtained from $V = 0$ to $V = 50$ volts.

3. Results with Helium Valve.

A set of characteristics with varying filament volts (v_f) are shown in Fig. 3. They were obtained with the R 2 A valve used in the previous work. The (I, V) characteristic for $v = 3{\cdot}4$ volts is shown on the same scale. The following points are of interest:—

At A ($V = 10$) there is a suggestion of a deviation which is just noticeable

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with high filament temperatures; the similarity in the change in both the grid and plate current curves possibly denotes a very slight abnormal increase in the electron current to both the grid and the plate.

At B ($V = 21$) a more marked change in the current values occurs. In this case the grid current (i) commences to increase.

Between 25 and 26 volts—point C—a rapid rise in both currents takes place and continues until the plate volts (V) attain a value of 30.

At this point D, the grid current again commences to decrease; the change being quite sudden with high filament temperatures. The steady decrease continues until the current is zero and then changes sign. Mean-

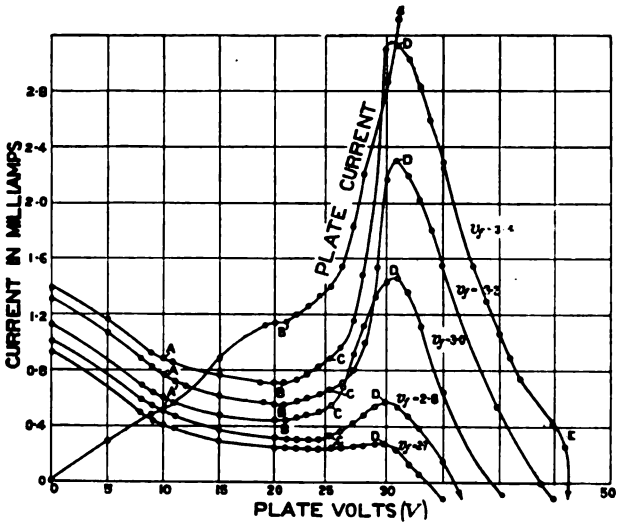

FIG. 3.—R 2 A (He) Valve. $v = 8{\cdot}0$ volts.

while the plate current steadily increases but at a much greater rate than previously.

The point E ($V = 45$) was only noticeable at filament voltages about 3·4, for which values of v_f the grid current did not change sign at plate voltages less than 45.

Reference to Fig. 3 shows that as the filament temperature was decreased the curves were considerably modified.

It may also be mentioned that a reduction of the grid voltage produced similar modifications; for example, the characteristic for zero grid volts is comparable to that for which $v_f = 2{\cdot}7$ in Fig. 3.

It is interesting to note that Professor Horton and Miss Bailey when using helium contaminated with mercury obtained a sudden increase in current at about 30 volts which they describe as an abrupt increase " at an electron velocity a few volts above that at which ionisation of the helium can occur."

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TABLE I.

Point.	$(V + E - v_f/2)$ Volts.					
	$v_f = 2{\cdot}7$	2·8	3·0	3·2	3·4	Mean.
A	—	—	—	10·8	10·0	10·4
B	—	?	20·3	21·0	21·0	20·7
C	?	24·8	25·2	26·3	25·8	25·5
D	30·0	30·0	30·8	30·8	30·3	30·4
E	—	—	—	—	45·8	45·8

The curves of Fig. 3 tend to show that this is an effect occurring in addition to the ionisation of helium, which causes a separate change in curvature at point C. In other words, since there are two distinct changes in the slope of the same characteristic, there must be two independent phenomena producing these changes. (See also p. 122.)

The value of the plate potential (V) for the various critical points does not give the true voltage fall through which an electron passes in travelling from the filament to the plate. A more exact expression is:—

$$V + E - v_f/2$$

where E is the emission velocity in equivalent volts with which an electron leaves the filament and v_f is the voltage fall along the straight filament. The correction $(E - v_f/2)$ has been found* to be approximately constant and for the R 2 A valve in use was equal to − 0·2 of a volt.

The corrected values for the potentials of the various critical points in the (i, V) characteristics of the helium valve are given in Table I.

These curves were repeated for a different R 2 A valve in which it was possible to raise the filament volts to 5·8. The following modifications were noticed and are shown on Fig. 4.

(1) Five critical points were obtained, namely at corrected plate potentials of 15·2, 19·8, 25·1, 54·5 and 80·5 volts. The

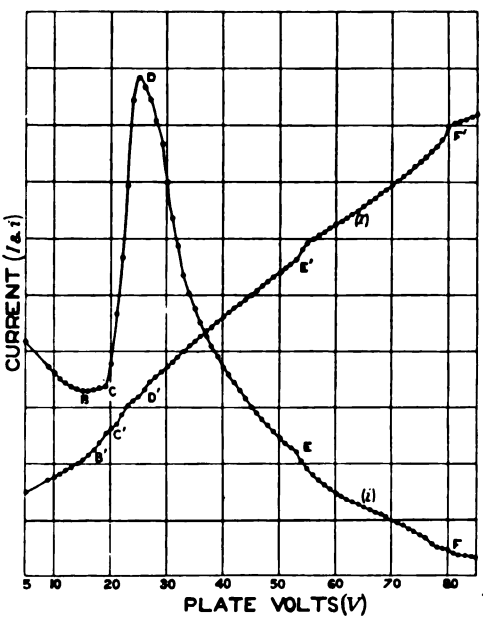

FIG. 4.—R 2 A (He) Valve. v = 8·0 volts. v_f = 5·8 volts.

* Hodgson and Palmer, *loc. cit.*

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same correction was used as before, namely $(E - v_f/2)$ but owing to the high filament temperature it is certain that electrons with the requisite energy were emitted in considerable numbers from points much nearer to the comparatively cold filament supports, in which case $v_f/2$ is too large a deduction. This is probably the reason why the above values, which correspond to critical potentials previously obtained, are somewhat lower.

(2) The last point was obtained below the plate voltage axis.

(3) The discontinuities at 54·5 and 80·5 were extremely small compared with the effects at 19·8 and 25·1; the latter point in particular being a high peak of type D (Fig. 3).

The results are tabulated below; the letter indicating the type of bend as in Fig. 3.

TABLE II.

Point.	$(V + E - v_f/2)$ Volts.
A	—
B	15·2
C	19·8
D	25·1
E	54·5
F	80·5

The change in curvature about 30 volts may be a further effect corresponding to the point D of Fig. 3, but there is no apparent discontinuity in the characteristic.

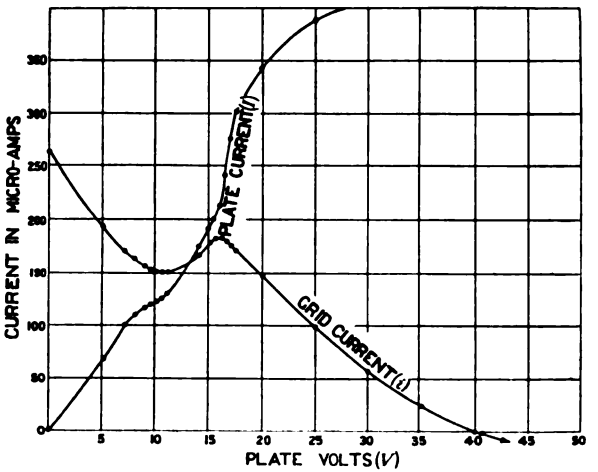

FIG. 5.—N. P. L. No. 2 (Hg) Valve. $v_f = 3{\cdot}2$ volts.
$v = 8{\cdot}0$ volts.
$E = 2{\cdot}0$ volts.

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4. Results with Mercury Valve.

Fig. 5 shows the characteristics obtained from an N. P. L. No. 2 valve which contains an amalgamated silver plate. Using the same lettering as in the previous table for similar types of change in the characteristic slope, the corrected values of the corresponding plate potentials are given in Table III.

TABLE III.

Point.	$(V + E - v_f/2)$ Volts.
A	—
B	10·9
C	—
D	15·4
E	—

5. Results with Argon Valve.

The set of characteristics shown on Fig. 6 were obtained by varying the relative pressures of a mixture of argon and mercury vapour. The filament temperature and grid volts were kept constant throughout, although three different valves of similar geometry had to be used owing to the rapid disintegration of the filament under the bombardment of the argon ions. The Curves I., II. and III. (Fig. 6) were obtained with one valve, Curves IV. and V. with a second, and Curve VI. with the third valve.

To obtain Curve I. precautions were taken to freeze out all mercury vapour, whilst the electrodes were bombarded during evacuation to rid them

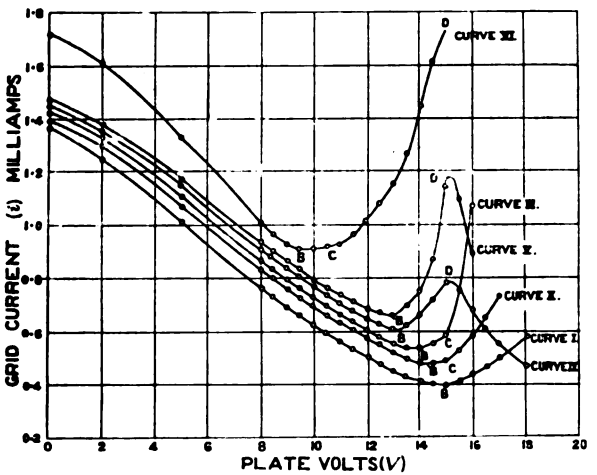

FIG. 6.—R (A + Hg) Valve. v = 3·2 volts.
v = 8·0 volts.
E = 3·1 volts.

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of occluded gas. With Curves II. to VI. the mercury vapour pressure was progressively increased and argon added from a side tube till the total pressure was about ·04 mm. of mercury in each case.

Curve I. is similar to that obtained when previously determining the ionising potential of argon. Curves II., III., IV. and V., show the plate potential of the bend B gradually approaching a value of 13·0 volts as the impurity (mercury vapour) is increased.

With Curves II. and III. the bend C occurs at the same plate voltage as point B of Curve I. whilst with Curves IV. and V. and probably VI. the bend D occurs at this particular value of the plate potential.

With Curve VI., for which the argon may be looked upon as an impurity in a mercury valve, the curve is similar to that of Fig. 5 with an additional bend at about 11 plate volts. (See paragraph **6.**)

For these valves the value of the plate potential correction was about + 1·5 volts but varied slightly with the different valves. Table IV. gives the corrected plate potentials for the various critical points which have been lettered in the same manner as the curves of Fig. 3. From this table it can be seen that

TABLE IV.

Point.	$(v + E - v_j/2)$ Volts.					
	Curve I.	Curve II.	Curve III.	Curve IV.	Curve V.	Curve VI.
A	—	—	—	—	—	—
B	16·5	15·7	15·5	14·5	14·3	10·7
C	—	16·5	16·5	—	—	12·5
D	—	—	—	16·5	16·7	16·5
E	—	—	—	—	—	—

the corrected value of the plate potential for the point B gradually decreases from 16·5 volts in Curve I. to 14·3 volts in Curve V. Thus, if as was assumed in the previous paper (*loc. cit.*), this bend be taken to indicate the ionisation potential of argon, the value obtained will be subject to a variation ranging from 16·5 volts to a value which apparently approaches 12·5 volts; that is from the true ionisation potential of argon to its resonance potential. But the dependence of this variation upon the amount of impurity present is in accordance with Horton's results in helium, which he explained by Bohr's statement that the radiation from such a gas will be capable of ionising any impurity, the ionising potential of which is less than the resonance potential of the chief gaseous constituent.* A similar explanation can therefore be applied to account for the above results and probably explains the low value of the ionising potential of argon recorded by Stead and Gossling.

On the other hand, if the atom is more readily ionised after it has absorbed the energy radiated from an adjacent atom (see p. 114) an increase in total pressure (*i.e.*, in the number of atoms present) should increase the radiation

* See p. 114.

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in the tube and hence the probability of ionisation occurring would also be increased. This effect would be independent of the presence of impurities. To test this, Curve I. of Fig. 6 was reproduced with argon at pressures of 0·10 mm, 0·07 mm and 0·01 mm of mercury (Fig. 7). The same precautions were taken to freeze out mercury vapour. The curves show a slight reduction in the value of the point B: the critical potentials being 15·8, 16·3 and 16·6 respectively. Although the effect is smaller than that produced by the addition of impurities, it tends to show that ionisation of unstable atoms (*i.e.* of atoms which have absorbed radiation from neighbouring atoms which have been previously impacted) is taking place, causing a reduction in the usual ionisation potential observed at low pressures.

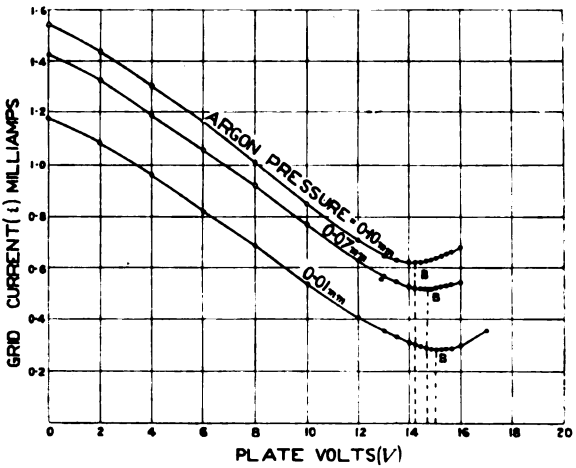

FIG. 7.—R (A) Valve.
v = 8·0 volts.
v_f = 3·2 volts.
E = 3·2 volts.

Pressure in mm of Hg.	Critical Potential.	
	From Graph.	Corrected.
0·10	14·2	15·8
0·07	14·7	16·3
0·01	15·0	16·6

6. Discussion.

Whatever physical phenomena are occurring in the valves at the various critical points, it is of importance to note that each change of grid current is accompanied by an increased current to the plate (see Figs. 3 and 5). In no case does the plate current decrease. The same effect is seen in the grid current for the bends of type A, B and C. Types D and E are abnormal decreases in grid current.

The increases in the plate current may be accounted for by either :—

(*a*) an increased number of electrons arriving at the plate, or
(*b*) an increased number of positive ions leaving the plate.

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Horton* has shown that the latter effect can take place under the bombardment of electrons but such an explanation is precluded in the present case by the regularity of the plate current characteristic of a hard valve (Fig. 1). We are thus left with the first possibility. If ionisation is occurring in the tube the bombardment of the filament by the resulting positive ions will cause an abnormal increase in the filament emission and consequently an abnormal increase in the plate current. Since ionisation can occur at the critical points A, B and C, it is probable that the foregoing explanation accounts for these particular changes of characteristic slope and that these critical points are therefore due to ionisation. The corresponding points in the grid current curve can be explained in the same way; although, if the ionisation is occurring between the grid and the plate, a certain percentage of the positive ions will also be collected by the grid.

It is therefore conceivable that, should sufficient positives be produced between the grid and the plate, the grid current will be considerably reduced or even reversed. Such an occurrence will explain the critical points D and E and the decreasing grid current will be the result of an ever increasing number of positive ions being collected by the grid. At the point where the grid current curve crosses the plate voltage axis the number of electrons and positive ions arriving at the grid from opposite directions will be equal. Since a bend of type D can occur when $V = 16{\cdot}5$ volts in argon (Curves IV. and V. of Fig. 6), and a similar effect has been obtained in helium at 25·5 volts (Fig. 4), at which potentials ionisation is known to take place, the above explanation is all the more probable.

Again since the point D, from this standpoint, depends upon the relative number of electrons and positive ions arriving at the grid, there is no particular reason why the change in direction should not occur at any critical voltage at which an increase in ionisation occurs.

Thus the occurrence of the point D at 30·4 volts in helium may indicate a sudden increase in the ionisation at this potential. Horton found a sudden increase at this potential whilst from Bohr's theory ionisation is to be expected at 29·4 volts. On the other hand the value 30·4 is approximately the sum of the ionisation potential of mercury and the resonance potential of helium. In other words, it is possible for one electron to cause ionisation of the mercury vapour by direct impact and also to gain sufficient energy to ionise indirectly by causing the emission of ultra violet light from the helium atom, before the electron reaches the anode.

Again 30·4 volts is exactly double 15·2 volts at which potential critical points were obtained in both helium and mercury valves (Figs. 4 and 5). Hence the discontinuity at 30·4 may be due to the presence of carbon monoxide or water vapour, the ionising potentials of which are about 15 volts. Such gases may easily be present in these valves, and their presence has been detected by Stead and Gossling† in valves not nominally containing either carbon compounds or water vapour.

* *Proceedings of the Royal Society*, 95A, p. 408, 1919.
† *Philosophical Magazine*, 40, p. 421, October, 1920.

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A similar effect, if due to the presence of both mercury and helium might be expected at (10·4 + 25·5) volts; but no such critical point could be detected. This makes it more probable that the bend at 30·4 volts is either that predicted by Bohr and is therefore due to further ionisation of helium or is due to the presence of other impurities (see below).

Point E ($V = 45·8$) is particularly interesting as this confirms the work of Professor Horton and Miss Davies* in which they obtained a critical value at about 47 volts. In their opinion such a point arises from a second radiation potential, the theoretical value of which is (20·4 + 25·6) volts.

Finally, if the slight change in curvature at the point where $V = 40—41$ is a real effect, it can be accounted for either by the (20·4 × 2) volt radiation which must occur here, or by the radiation from the helium atom which has lost one electron. Bohr's theory gives a value of 40·6 volts for radiation from a charged helium atom.

Whatever may be the explanation of the points D and E, the changes at B and C enable the ordinary resonance and ionisation potentials of impure gases to be determined, whilst for a pure gas point B gives the first true ionisation potential.

Under certain conditions the point D will record the ionisation potential as in Fig. 4 and in Curves IV. and V. of Fig. 6.

From Fig. 4 a further confirmation of Horton's results is obtained, and further support to the suggestion that the 30·4 volt critical point of Fig. 3 is due to impurity and not to a true ionisation of helium. Point B (Fig. 4) ($V = 15·2$) can only be accounted for by direct ionisation since it is below the first resonance potential of helium, which causes the bend C. Hence it is concluded that point B is due to the presence of either carbon monoxide or water vapour or both. Points C and D are due respectively to the resonance and ionising potentials of helium. Points E and F can be explained by Bohr's theory which predicts double ionisation of helium at 82·9 volts (point F), and hence the loss of the second electron at (82·9 − 25·6) volts from the previously ionised helium atom. Using the data of these experiments this effect should be apparent at (80·5 − 25·1) volts or 55·4 volts, and was actually detected at 54·5 volts. No effects were apparent at any other points on the characteristic.

Referring to the mercury valve curves of Fig. 5, the bend B gives the true ionisation potential of mercury whilst point D is probably due to the presence of CO, as has already been indicated in reference to helium.

Should the resonance potential of the impurity be greater than 10·4 volts, in the case of a mercury valve, a further bend (type C) would be expected with a value between 10·4 and 15 volts. This effect is seen in the appearance of such a bend in Curve VI. of Fig. 6 where the resonance potential of argon (12·5, Table IV.), has caused an additional increase by ionising the mercury vapour.

From the foregoing discussion the argon curves are easily explained. The point B moves to the left as the mercury pressure is increased, thus

* *Philosophical Magazine*, 39, p. 597, 1919 (Fig. 3).

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showing the true ionisation potential to be 16·5 (Curve I.), and from Curve VI. the true resonance potential is 12·5.

It was not found possible to continue these curves as in the case of helium owing to the breaking of the filament which occurred with the higher plate potentials. It is hoped to continue these experiments using a valve with a thicker filament.

The curves of Fig. 7 show that similar effects may be produced on a smaller scale by an increase in the pressure of pure gases.

7. Applications.

The circuit shown in Fig. 8 was used to test the rectifying properties of the various bends. The rectification, if any, above point C could not be detected owing to the valve noises which completely drowned any signal which might have been received.

At the bend C the rectification was found to be appreciable as long as the plate potential was just less than the ionising potential of the gas. A slight

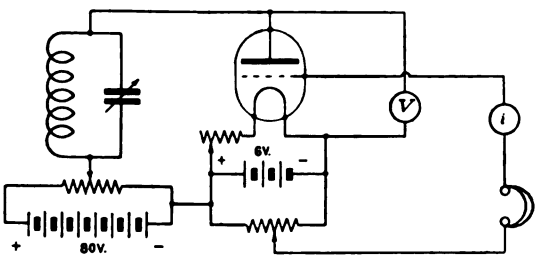

FIG. 8.

increase in V would immediately produce noises which effectively interfered with reception.

The intensity of the note when compared with that produced by the usual rectifying circuit was found to be in the approximate ratio of 0·6 : 1·0.

The decreasing slopes of the characteristic suggest the use of the valve as a negative resistance tube similar to the dynatron in which case the reversal of current is due to the secondary emission of electrons from the positive electrode. This method of employment is now being investigated.

8. Conclusions.

From the foregoing experiments it is concluded that :—

(1) The (i, V) and the (I, V) characteristics of a soft three-electrode valve can be utilised to determine the resonance and ionising potentials of the contained gas.

(2) The nature of the gas and the presence of impurities can be determined from the various critical points in these characteristics.

(3) Certain methods of measuring ionisation potentials are liable to error if impurities are present.

(4) The work of Professor Horton and Miss Bailey in which a trace of

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mercury vapour was found to cause ionisation phenomena in helium at potentials ranging from the true ionisation potential to the resonance potential has been confirmed.

(5) This result has been extended to argon, in which gas traces of mercury vapour were found to cause similar effects.

(6) The observed value of the ionisation potential in a pure gas decreases slightly with increase of gas pressure causing changes in the characteristics similar to those produced by the addition of impurities.

(7) The following are the critical potentials obtained for helium and argon:—

Gas.	Resonance potentials (volts).	Ionising potentials (volts).
Helium	20·7	25·5 (removal of 1st electron).
	45·8	54·5 (removal of 2nd electron).
	(41 ?)	80·5 (removal of both electrons).
Argon	12·5	16·5

The above experiments were carried out in the Physics Department of the University of Bristol, and my best thanks are due to Professor A. M. Tyndall for his interest and advice during the work and for the facilities placed at my disposal.

The expenses entailed in this research were met by a grant from the University of Bristol Colston Research Fund.

The Physics Department,
The University, Bristol.

The Paris Radio Central.*

On January 9th, 1921, the foundation stone of the new Paris Radio Centre was laid in the grounds of the Château of Sainte-Assise, near Paris. The ceremony was performed by M. Louis Dechamps, the Under Secretary of State for the French Postal Telegraph Administration. A large number of official representatives were present amongst whom may be specially mentioned—General Ferrié, the Inspector-General of French Military Telegraphs, Captain Lagorio, the Director of the wireless branch of the Postal Telegraph Administration, M. Girardeau of the Cie. Générale de Télégraphie sans fil, and M. Brenot, Technical Director of the Société Française Radioélectrique.

The construction and working of this Radio Centre is being undertaken by the Compagnie Générale de Télégraphie sans fil, and its completion will give to France an incontestable superiority in the field of radio communications, and will enable the insufficiency of the cable communications to the French colonies and to other oversea countries to be overcome.

* Abstracted from information contained in the articles referred to in Abstracts Nos. 1542—1545 (see p. 156 in this issue).

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The Paris Radio Central will comprise the following:—

An intercontinental transmitting station capable of an aerial output of from 200 to 1,500 kW according to the range to be covered.

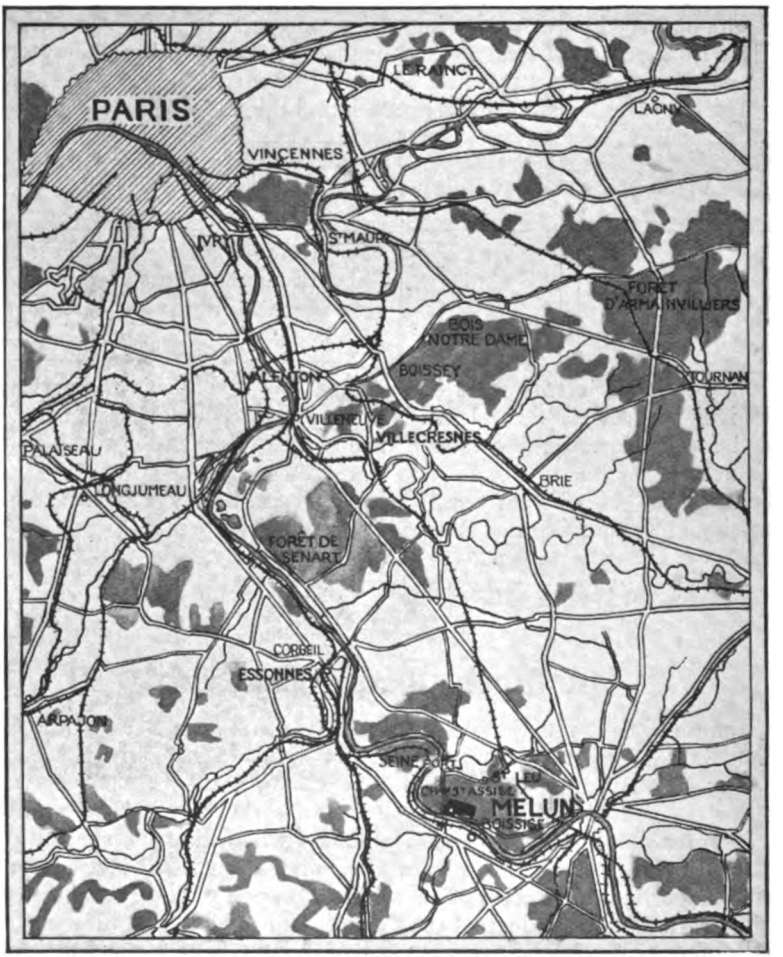

FIG. 1.—Map showing the location of the Transmitting Stations at Sainte-Assise, and the proposed sites for the Receiving Centres.

A Continental transmitting station capable of an output of 1 to 100 kW in the aerial, according to the distance to be covered.

One, and later two, receiving centres, each having seven groups of receiving apparatus.

A Central Bureau which may be likened to the nerve centre of the whole organisation.

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Site of the Stations.

The two transmitting stations will be adjacent to one another for convenience in erection and control, but will be entirely distinct in buildings, machines, etc. The choice of a suitable site to comply with all the conditions laid down by the Postal Telegraph Department was not easy, and the one finally adopted was on the plateau of Sainte-Assise, twenty-five miles from Paris (Fig. 1). The site is bounded on the north by the road from Seine-Port to Saint-Leu, on the south and west by the Seine, and on the east by the railway from Melun to Brunoy. The site is approximately level, and a few metres below the surface sufficient ground water is present to ensure an adequate earth connection.

The "Intercontinental" Transmitting Station.

The station for intercontinental communication will be controlled from the Central Bureau at Paris, and will ensure regular and rapid communication

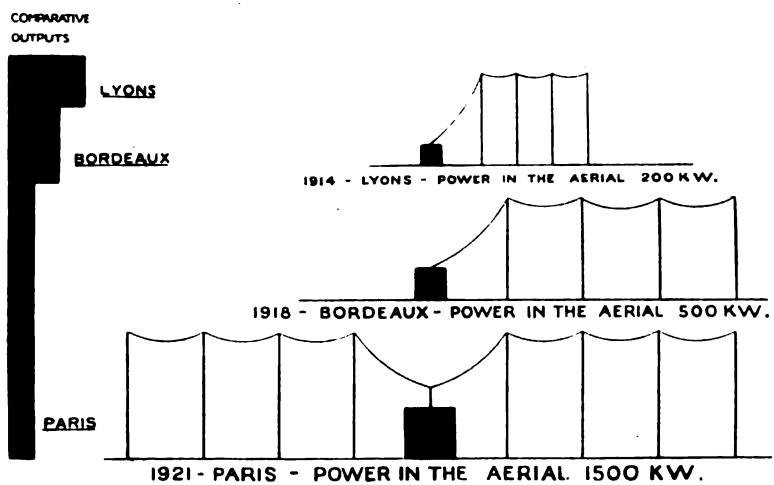
COMPARATIVE OUTPUTS
LYONS
BORDEAUX
PARIS
1914 - LYONS - POWER IN THE AERIAL 200 KW.
1918 - BORDEAUX - POWER IN THE AERIAL 500 KW.
1921 - PARIS - POWER IN THE AERIAL 1500 KW.

FIG. 2.—Comparative sizes of recent French Radio Stations.

with North, Central and South America, with Asia, and with South Africa. It will contain three high-frequency alternators each capable of delivering an output of 500 kW to the aerial. Each machine will be driven by a 450 kW, D.C. motor. These alternators can be used either separately or in conjunction, or can be grouped for two simultaneous transmissions, each of 250—500 kW antenna output, while eventually it is intended to provide for coupling the three machines to a single antenna to give an output of 1,500 kW (Fig. 2). The complete installation will comprise the antenna couplings, the control and regulating desks, the antenna loading inductances, the switchboards and auxiliary machines. Transmission will be possible at a speed of more than 100 words per minute at full power, so that with two

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simultaneous transmissions the total output will exceed 12,000 words per hour.

Two sources of power supply will be available—from a power distribution network, and from an emergency installation of three Diesel engines, each of 1,800 H.P.

The aerial, of roughly twice the size of that at Bordeaux * will be supported by sixteen towers, 250 metres (830 feet) high, and will form a symmetrical double network covering an area of about 910,000 square metres (1·088 million square yards). About forty-three miles of aerial cable will be used in its construction, together with nearly ten miles of steel supporting cable.

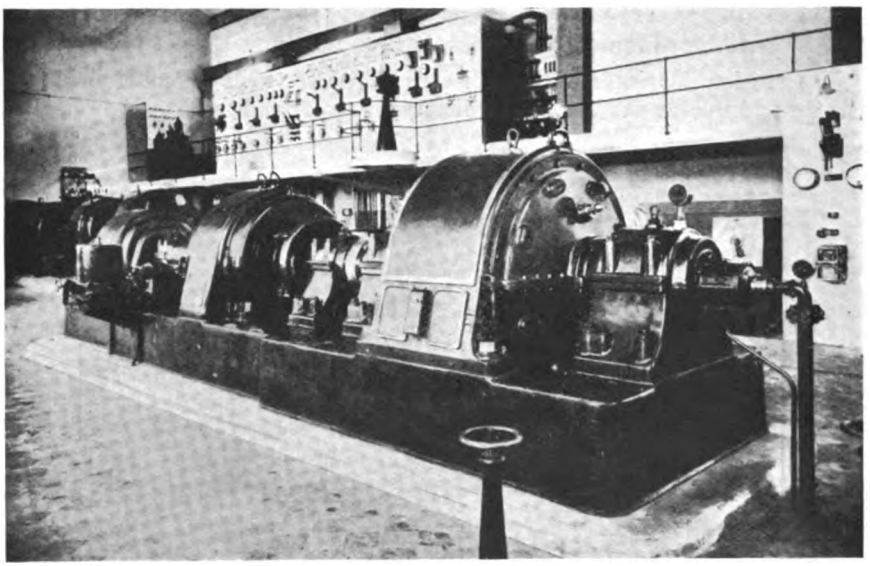

FIG. 3.—A high-frequency Alternator (200 kW output) of the type to be used in the Paris Radio Central Station.

The two halves of the aerial may be used separately for two simultaneous transmissions of reduced power, or they may both be grouped together for full power work. The earth system will be connected at numerous points with the ground water, and will consist of 800 square metres (950 square yards) of copper plates near the centre of the station building, together with 80,000 metres (forty-nine miles) of copper wire buried under the aerials, and covering a surface of over two million square yards in area.

The station building will be divided into three parts—containing respectively (1) the high-frequency machines and their accessories; (2) the power units (Diesel engines and generators), the workshops and stores; and (3) the offices, etc.

* See p. 87 of our last issue.

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The "Continental" Transmitting Station.

Situated in the immediate neighbourhood of the intercontinental station, this one will serve for regular radio traffic within a radius of 3,000 km from Paris. It also will be controlled directly from the Central Bureau in Paris. It will contain two complete transmitting units each comprising two high-frequency alternators with an output of 25 aerial kW each. They can be arranged either for a single transmission with a power of from 12 to 100 kW in the aerial, or for two simultaneous transmissions of 12 to 50 kW each.

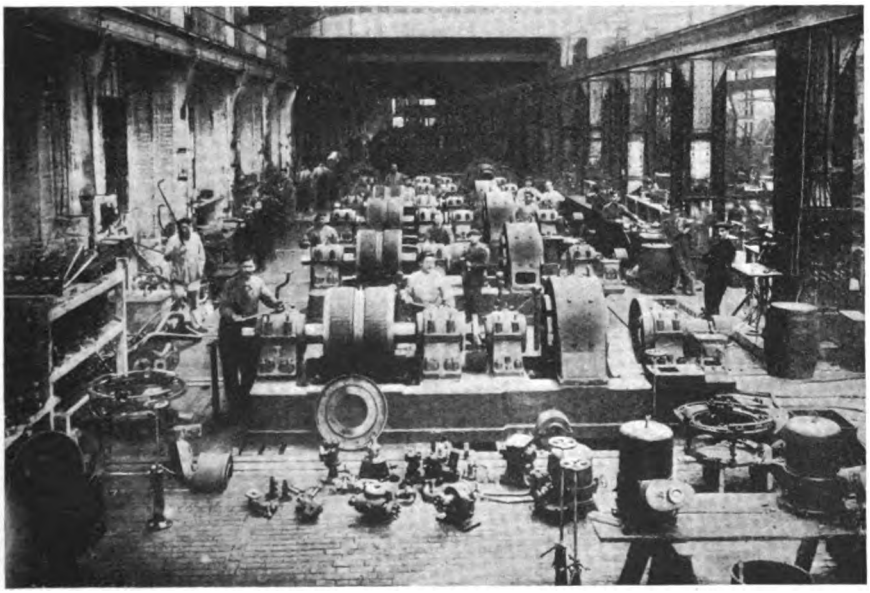

FIG. 4.—A group of large High-frequency Alternators under construction in the Works of the Société Alsacienne de Constructions Mécaniques at Belfort.

Transmission may be effected with a speed of over 100 words per minute at full power.

As in the case of the larger station, an auxiliary power supply will be provided in the form of two Diesel engine generators of 160 H.P. each.

The aerial of the " double cone " type will have four independent networks and will be supported by a single guy-supported tower 250 metres (830 feet) in height, and by thirty-six auxiliary poles 10 metres high. It will contain thirteen miles of aerial cable and nine miles of steel supporting cable. The earth system will consist of 200 square metres (240 square yards) of copper plates and ten miles of buried copper wires.

The buildings of the Château of Sainte-Assise already in existence will be utilised eventually for auxiliary radio services and transmitting installations for new communication routes.

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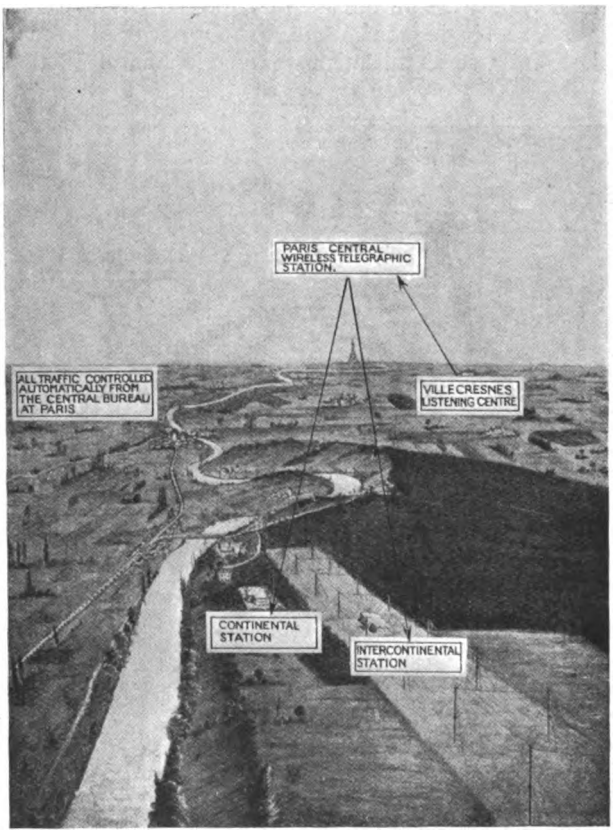
The Receiving Centres.

The sites for these stations that have been tentatively decided upon are at Villecresnes, 22 kms S.S.E. of Paris, at Essonnes, 30 kms south of Paris, and Valenton, 18 kms S.S.E. of Paris. (See Figs. 1 and 5.)


PARIS CENTRAL WIRELESS TELEGRAPHIC STATION.
ALL TRAFFIC CONTROLLED AUTOMATICALLY FROM THE CENTRAL BUREAU AT PARIS
VILLECRESNES LISTENING CENTRE
CONTINENTAL STATION
INTERCONTINENTAL STATION

(*Radioélectricité.*)

FIG. 5.—The Paris Radio Central Station.

The first reception centre will in its initial stages contain three receiving stations for communications with North and South America, and with Asia, two stations for European traffic, and one for training purposes. Each receiving station will contain, (1) a double set of selective receiving apparatus with a frame aerial; high and low-frequency amplifiers, heterodynes, anti-atmospheric devices, together with the necessary batteries and valves, all enclosed in a screened cabin; and (2) automatic photographic or phonographic recording apparatus for high-speed working (Figs. 6 and 7).

The whole apparatus will be made sufficiently sensitive and selective to

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carry on duplex working with the American stations, without the use of any antenna or frame aerial external to the receiving apparatus. The receiving

FIG. 6.—Photographic Recording Apparatus.

centre will be connected by direct telephone lines with the Central Bureau, and the incoming telegrams will be sent on to the Bureau by means of two

FIG. 7.—Phonographic Recording Apparatus.

sets of quadruplex Baudot apparatus. Each receiving centre will consist of six to eight single story buildings containing the frame aerials, the anti-atmospheric and receiving apparatus, and one central building devoted to the reception and recording of the messages picked up by the frame aerials,

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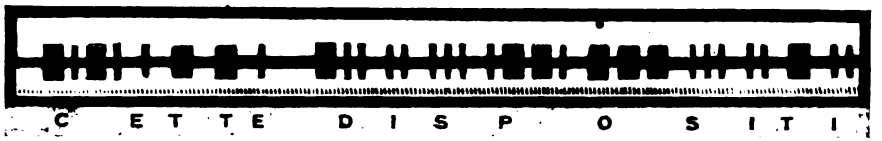

FIG. 8.—Type of Record obtainable with the Photographic Recording Apparatus at a speed of 12,000 words per hour.
The lower line of dots shows the vibrations of a tuning-fork having a frequency of 200 per second.

to the land line telegraphic traffic and to auxiliary services. This building will be about 220 yards distant from the frame aerials.

The Central Bureau.

This bureau will be located near the heart of Paris and besides containing the quadruplex telegraphic apparatus connecting it with the receiving stations and with the other land line telegraphic distribution services, will contain the apparatus for the distant control of all the distant transmitting apparatus included in the scheme. It is estimated that when working at full capacity this system will be capable of dealing with about two million words per twenty-four hour day.

Some samples of the type of record obtainable with the photographic recording apparatus proposed for use in the receiving stations are given in Fig. 8. The anti-atmospheric arrangements to be employed are based on the utilisation of a series of coupled and tuned filtering circuits forming a

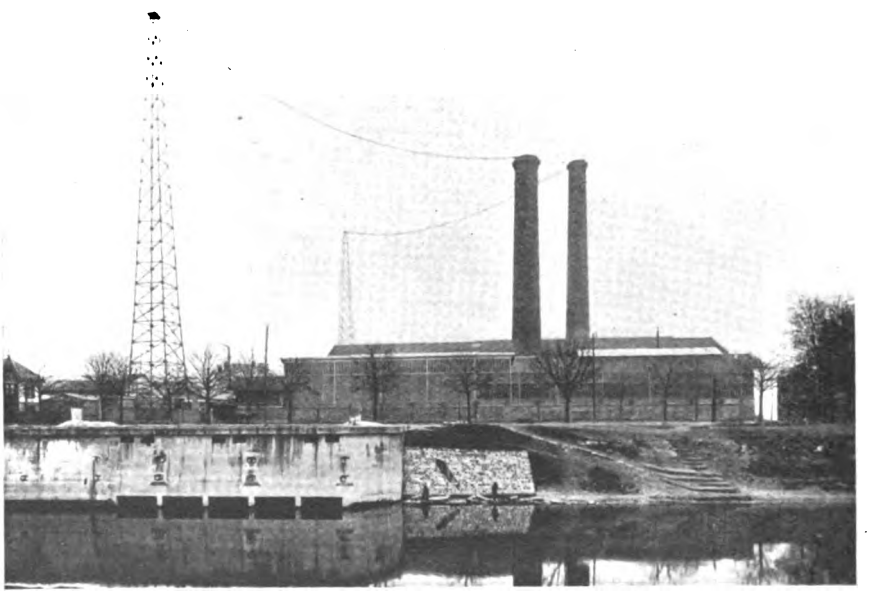

FIG. 9.—The Paris Terminal of the London-Paris Service at the Levallois Works of the Société Française Radioélectrique.

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species of "artificial line." This arrangement also gives great selectivity and enables a receiving station to be operated quite close to a transmitter provided that there is not less than 2 per cent. difference between the wavelengths of the two stations.

The London-Paris Service.

While awaiting the completion of the larger schemes outlined above, the Compagnie Générale de Télégraphie sans fil has announced its intention of inaugurating certain preliminary communication routes where the traffic is the heaviest. The first of these to be put into service was that between London and Paris which was opened during January.* The London end of the service is a station near Chelmsford operated by Marconi's Wireless Telegraph Co., while at the Paris terminal a station at the Levallois works of the Société Française Radioélectrique has been employed (Fig. 9).

A temporary Central Bureau has been opened in Paris at 79 Boulevard Haussmann. The actual radio transmission is controlled by a perforated tape of the Wheatstone type, a valve transmitter, delivering 2·5 kW in the aerial, being employed. The towers at the transmitting station illustrated in Fig. 9, are 225 feet high. Reception is effected on a frame aerial in the Central Bureau. Phonographic reception of the messages is adopted, the records being subsequently run over at a lower speed and transcribed by ear.

A Note on the Theory of the Thermionic Tube.

By J. A. FLEMING, M.A., D.Sc., F.R.S.

In the *Physical Review* for 1913 (vol. 2, p. 453) and also in the *Proceedings of the Institute of Radio Engineers* for September, 1915 (vol. 3, p. 269) Mr. Irving Langmuir has given equations for the thermionic current i between a hot and cold cathode and anode in terms of their potential difference V and proved that i varies as $V^{\frac{3}{2}}$. This proof depends upon certain assumptions which are not justifiable, but my object here is not to criticise these postulates but to give a proof of the equation for one particular case and point out a small error (as I think) in the solution as given by Mr. Langmuir in the *Physical Review*.

The case considered is that of a hot wire, the radius of cross section of which is a, placed in the axis of a cylindrical anode, the radius of which is R, kept at a potential V_0.

Let V be the potential at a point at distance r from the centre of the wire.

Assuming then that ρ is the density of the space charge at that point and v the velocity of the electrons the thermionic current per unit length of the cathode is,

$$i = -2\pi r\rho v \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

If we *assume* that the electrons are emitted from the cathode without

* See p. 99 in our last issue, Note No. **1914.**

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initial velocity, which is certainly not the case, and if we *assume* that the cathode is all at zero potential, which is not true, then we can say that,

$$eV = \frac{1}{2}mv^2. \quad \ldots\ldots\ldots \quad (2)$$

where e and m are the charge and mass of the electron.

Hence $$v = \sqrt{\frac{2e}{m}} \cdot \sqrt{V} \quad \ldots\ldots\ldots \quad (3)$$

Now at the point r the potential and density are connected by Poisson's equation which in polar form adapted to this case is

$$\frac{d^2V}{dr^2} + \frac{1}{r}\frac{dV}{dr} = -4\pi\rho \quad \ldots\ldots\ldots \quad (4)$$

Substituting from equations (1) and (3) we have

$$rV^{\frac{1}{2}}\left(\frac{d^2V}{dr^2} + \frac{1}{r}\frac{dV}{dr}\right) = 2i\sqrt{\frac{m}{2e}} \quad \ldots\ldots\ldots \quad (5)$$

or $$r\frac{d^2V}{dr^2} + \frac{dV}{dr} = \frac{A}{\sqrt{V}} \quad \ldots\ldots\ldots \quad (6)$$

where $A = 2i\sqrt{\frac{m}{2e}}$.

The problem then is, to solve (6). At first sight it looks as if it might be a form of Bessel's equation but I have not been able to reduce it to any typical form of Bessel's equation.

A solution applicable in the present case may be found as follows :—

Assume that a solution of (6) can be found in the form

$$V = r^n\,\phi(r) \quad \ldots\ldots\ldots \quad (7)$$

Where $\phi(r)$ is some function of r of the form $\phi(r) = \beta^m K$ and K is some constant.

We have to find the conditions under which $V = r^n\beta^m K$ can be a solution of (6).

We have then,

$$\frac{dV}{dr} = \left(nr^{n-1}\beta^m + r^n m\beta^{m-1}\frac{d\beta}{dr}\right)K$$

$$r\frac{d^2V}{dr^2} = \left(n\,n-1r^{n-1}\beta^m + nr^n m\beta^{m-1}\frac{d\beta}{dr} + nr^n m\beta^{m-1}\frac{d\beta}{dr} + \right.$$

$$\left. + r^{n+1}m\,\overline{m-1}\beta^{m-2}\left(\frac{d\beta}{dr}\right)^2 + r^{n+1}m\beta^{m-1}\frac{d^2\beta}{dr^2}\right)K$$

and $$\frac{A}{\sqrt{V}} = Ar^{-\frac{n}{2}}\beta^{-\frac{m}{2}}K^{-\frac{1}{2}} \quad \ldots\ldots\ldots \quad (8)$$

Hence in order that r^n may be a factor in the solution $d\beta/dr$ must contain a factor $1/r$ and $d^2\beta/dr^2$ must contain a factor $1/r^2$. Also β must be zero when $r = a$.

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A function which fulfils this condition is

$$\beta = \log\frac{r}{a} + a_2\left(\log\frac{r}{a}\right)^2 + a_3\left(\log\frac{r}{a}\right)^3 + \text{etc.} \quad . \quad . \quad . \quad . \quad (9)$$

Hence if we differentiate (9) and write $f(r)$ for $rd\beta/dr$ and $F(r)$ for $r^2d^2\beta/dr^2$ and substitute these values in (8) we have

$$Kr^{n-1}\{n^2\beta^m + (m + 2nm)\,\beta^{m-1}f(r) + m\overline{m-1}\beta^{m-2}[f(r)]^2 + \\ + m\beta^{m-1}F(r)\} = Ar^{-\frac{n}{2}}\beta^{-\frac{m}{2}}K^{-\frac{1}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

In order that r^n may be a factor in the solution we must have $\overline{n-1} = -\frac{n}{2}$ or $n = 2/3$. Substituting this in (10) we have

$$K\beta^{m-2}\left\{\frac{4}{9}\beta^2 + \frac{7}{3}m\beta f(r) + m\overline{m-1}[f(r)]^2 + m\beta F(r)\right\} = A\beta^{-\frac{m}{2}}K^{-\frac{1}{2}} \quad . \quad (11)$$

Hence in order that β^m may be a factor in the solution we must have $m - 2 = -m/2$ or $m = 4/3$ and also the contents of the large bracket in (11) must be unity.

Hence we have

$$\frac{4}{9}K\{\beta^2 + 7\beta f(r) + 3\beta F(r) + [f(r)]^2\} = AK^{-\frac{1}{2}} \quad . \quad . \quad . \quad . \quad (12)$$

We have finally to find the conditions that the contents of the large bracket in (12) may be unity.

Let $x = \log\frac{r}{a}$, then we have,

$$\beta = x + a_2x^2 + a_3x^3 + a_4x^4 + \text{etc.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

$$\beta^2 = x^2 + 2a_2x^3 + (2a_3 + a_2^2)x^4 + (2a_4 + 2a_2a_3)x^5 + \text{etc.} \quad . \quad . \quad . \quad (14)$$

$$f(r) = 1 + 2a_2x + 3a_3x^2 + 4a_4x^3 + \text{etc.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

$$F(r) = (2a_2 + 1) + (6a_3 - 2a_2)x + (12a_4 - 3a_3)x^2 + \text{etc.} \quad . \quad . \quad . \quad . \quad (16)$$

Substituting these values in (12) we obtain

$$\frac{4}{9}K\{1 + (10a_2 + 4)x + (24a_3 + 12a_2 + 10a_2^2 + 1)x^2 + \\ + (44a_4 + 16a_3 + 36a_2a_3 + 8a_2^2 + 2a_2)x^3 + \text{etc.}\} \\ = AK^{-\frac{1}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

Hence in order that β^m may be a factor in the solution the coefficients of all the powers of x in the bracket in (17) must be zero, or,

$$10a_2 + 4 = 0 \qquad \therefore a_2 = -\frac{2}{5}$$

$$24a_3 + 12a_2 + 10a_2^2 + 1 = 0 \qquad \therefore a_3 = \frac{11}{120}$$

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$$44a_4 + 16a_3 + 36a_2a_3 + 18a_2^2 + 2a_2 = 0 \qquad \therefore\ a_4 = -\frac{47}{3300}$$

$$\text{and also } \frac{4}{9}K = AK^{-\frac{1}{2}} \qquad \therefore K = \left(\frac{9}{4}A\right)^{\frac{2}{3}}.$$

Accordingly $V = \left(r\beta^2\frac{9}{4}A\right)^{\frac{2}{3}}$ is a solution of (6) and we have

$$i = \frac{2}{9}\sqrt{\frac{2e}{m}}\,\frac{V^{\frac{3}{2}}}{r\beta^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

where

$$\beta = \log\frac{r}{a} - \frac{2}{5}\left(\log\frac{r}{a}\right)^2 + \frac{11}{120}\left(\log\frac{r}{a}\right)^3 - \frac{47}{3300}\left(\log\frac{r}{a}\right)^4 + \text{etc.} \quad . \quad . \quad (19)$$

This agrees with Langmuir's solution (although he gave no detailed proof) with the difference that in his equation for β the coefficient of the second term is given as $\frac{2}{3}$ instead of $\frac{2}{5}$.

Since Langmuir's solution has been reproduced by other writers without proof and without correction of the above slip (as I think) it seemed worth while to put on record what I believe is the correct solution of the equation (6) above given.

Editorial Note.

With reference to the above paper, the discrepancy pointed out by Professor Fleming between his result and that obtained by Langmuir is merely due to a printer's error in Langmuir's paper in the *Physical Review*, where in equation (18) the coefficient of γ^2 is given as $\frac{2}{3}$ instead of $\frac{2}{5}$. The coefficient of γ^3 which involves that of γ^2 is correctly given, and by checking any one of the numerical values in Langmuir's Table I., it is seen at once that they are correctly calculated, *i.e.*, with $\frac{2}{5}\gamma^2$ and not with $\frac{2}{3}\gamma^2$. Professor Fleming has done a useful service, however, in pointing out the error in the equation as printed and in giving another method of solving the equation. As Professor Fleming mentions, Langmuir does not give the details of his solution, but it is a relatively simple matter and as it deals with a subject of some importance we have worked it out and give it here, so that readers can compare it with Professor Fleming's method.

a is the radius of the filament, V the potential at any radius r, i the current, e and m the charge and mass respectively of the electron. Then the equation to be solved is :—

$$r\frac{d^2V}{dr^2} + \frac{dV}{dr} = i\sqrt{\frac{m}{e}}\cdot\frac{2}{V} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

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Putting the solution in the form $i = \frac{2\sqrt{2}}{9}\sqrt{\frac{e}{m}} \cdot \frac{V^{\frac{3}{2}}}{r\beta^2}$ . . . . . (2)

we have to determine β. Substituting for i in the first equation it becomes

$$r\frac{d^2V}{dr^2} + \frac{dV}{dr} = \frac{4}{9}\frac{V}{r\beta^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where from (2) $$V = \left(\frac{i}{\frac{2\sqrt{2}}{9}\sqrt{\frac{e}{m}}}\right)^{\frac{2}{3}} r^{\frac{2}{3}}\beta^{\frac{2}{3}} = kr^{\frac{2}{3}}\beta^{\frac{2}{3}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where k is a constant for a given current i.

If from (4) we find $\frac{dV}{dr}$ and $\frac{d^2V}{dr^2}$ and substitute in (3) we obtain

$$3\beta r^2\frac{d^2\beta}{dr^2} + r^2\left(\frac{d\beta}{dr}\right)^2 + 7\beta r\frac{d\beta}{dr} + \beta^2 - 1 = 0 \quad . \quad . \quad . \quad . \quad (5)$$

Now putting $r = ae^{\gamma}$, $\frac{d\beta}{dr} = \frac{1}{r}\frac{d\beta}{d\gamma}$ and $\frac{d^2\beta}{dr^2} = \frac{1}{r^2}\left(\frac{d^2\beta}{d\gamma^2} - \frac{d\beta}{d\gamma}\right)$

equation (5) becomes

$$3\beta\frac{d^2\beta}{d\gamma^2} + \left(\frac{d\beta}{d\gamma}\right)^2 + 4\beta\frac{d\beta}{d\gamma} + \beta^2 - 1 = 0 \quad . \quad . \quad . \quad . \quad . \quad (6)$$

To find β in terms of γ, we assume the power series

$$\beta = \gamma + A\gamma^2 + B\gamma^3 + C\gamma^4 + D\gamma^5 + E\gamma^6 + \ldots$$

then $$\frac{d\beta}{d\gamma} = 1 + 2A\gamma + 3B\gamma^2 + 4C\gamma^3 + 5D\gamma^4 + 6E\gamma^5 + \ldots$$

Similarly $\frac{d^2\beta}{d\gamma^2}$, $\left(\frac{d\beta}{d\gamma}\right)^2$ etc., can be found and substituted in equation (6).

Since this equation must hold for all values of γ, the coefficients of the various powers of γ must each be equal to zero. The equation becomes

$$(10A + 4)\gamma + (10A^2 + 12A + 24B + 1)\gamma^2 + \ldots = 0$$

hence $$10A + 4 = 0 \quad \text{and} \quad A = -\frac{2}{5}.$$

Similarly $$B = \frac{11}{120} \qquad \text{and} \quad C = -\frac{47}{3300}$$

and $$\beta = \gamma - \frac{2}{5}\gamma^2 + \frac{11}{120}\gamma^3 - \frac{47}{3300}\gamma^4 + \ldots$$

This is the value of β which, inserted in equation (2), gives the current through the thermionic tube. As Langmuir points out, however, in most practical cases β approximates very closely to unity.

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Measurements of Radiation of Radiotelegraphic Aerials.

By G. VALLAURI.

(*Continued from page* 85.)

7. Measurement of the Resistance of the Receiving Circuit.— Having obtained the value of I_r, from the reading of the instruments and from the calibration constant, it is necessary to know the impedance of the receiving aerial to pass to the determination of the induced E.M.F. by means of (9). To determine the impedance the method chosen is to make the receiving aerial oscillate (either by the waves from the transmitter or by a local source of oscillations) with the same wavelength as is used in the measurements and to ascertain the variations of I_r through the effect of the insertion in the circuit of known supplementary impedances. The measurement is especially simple when the receiving circuit is in resonance, that is to say, when a variable condenser is inserted in it which is adjusted to obtain the maximum value of I_r. In this case, the reactance is null and the impedance is reduced to the mere total ohmic resistance. If then the receiving circuit is excited by a generator of persistent oscillations with a very loose coupling (as for example by the transmitting station itself), and a known resistance R' is inserted in series, the current is seen to diminish from the value I_r to the value I_r' and, as we may consider the induced E.M.F. to be constant, we get

$$R_r = R' \frac{I_r'}{I_r - I_r'} \quad \ldots\ldots\ldots \quad (10)$$

If, on the contrary, the excitation is made by damped oscillations and always with a very loose coupling, and at resonance, it is necessary to know besides λ and the decrement δ of the exciting oscillation, also the self-induction L (or the capacity C) of the receiving circuit* because then in the relation †

$$\left(\frac{I_r}{I_r'}\right)^2 = \frac{\delta_r'(\delta_t + \delta_r')}{\delta_r(\delta_t + \delta_r)} \quad \ldots\ldots\ldots \quad (11)$$

in which the decrements δ_r and δ_r' are equal to $\pi\sqrt{\frac{C}{L}}R_r$ and $\pi\sqrt{\frac{C}{L}}(R_r + R')$ respectively, R_r is the only unknown. Nor can there be any ambiguity in its determination although the relation is of the 2nd degree, since the equation gives only one positive physically acceptable solution.

---

* For this purpose it is sufficient to calibrate the variable tuning condenser, because then from the values of λ and C we get by the formula for resonance, $L = \frac{1}{4\pi^2 C}\left(\frac{\lambda}{u}\right)^2$.

† Deduced from the known expression for the current at resonance (see Zenneck-Seelig, *loc. cit.*, p. 105).

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Finally the measurement of R_r can be made by the addition of R' and with damped oscillations in the receiving circuit, using the method of excitation known as impulsion. For example, it can be applied by inserting in another circuit acting on the receiving circuit through a magnetic coupling (that is, inductively) a vibrator (or buzzer) producing rhythmic and sudden interruptions of current. At the moment of the breaking of the primary current, a portion of the stored energy of the magnetic field is set free in the receiving circuit and gives rise to an oscillation. If the working of the buzzer is regular and the reaction of the secondary current on the primary is negligible, it may be assumed that the power transformed into oscillatory current in the receiving circuit in the two cases (resistance R_r and $R_r + R'$) is the same; we get therefore

$$R_r = R' \frac{I_r'^2}{I_r^2 - I_r'^2} \quad \ldots\ldots\ldots \quad (12)$$

8. Calculation of the Effective Height.—Having measured I_r and deduced R_r by one of the experiments just stated, if the reception is made on an open aerial connected with the earth and equivalent to a half dipole h_r high, the effective height h of the sending antenna is found from equations (9a) (7) and (4), in which $\theta = \pi/2$ for the radiation at the earth's surface (or in the equatorial plane of the oscillator):

$$h = \frac{I_r}{I} \cdot \frac{dR_r\lambda}{4\pi\mu u h_r} \quad \ldots\ldots\ldots \quad (13)$$

If, on the contrary, the reception is made on a closed aerial, we have from (9a) (8) and (4), always supposing $\theta = \pi/2$

$$h = \frac{I_r}{I} \frac{dR_r\lambda^2}{8\pi^2\mu u S_r \cos\alpha} \quad \ldots\ldots\ldots \quad (14)$$

Equations (13) and (14) as well as (9a) from which they have been deduced, refer to the case in which the transmission current I is undamped. On the other hand, in the case when I consists of a series of damped oscillations of decrement δ_t, if it is assumed that the electromagnetic field at any point and especially at the receiving station is subject to the same exponential damping law as the current I, equations (4) (7) and (8) can still be considered valid by referring them to the new effective values of I, F, H and E.* For equation (9a) we substitute instead in this case the following (9b), in which appear the logarithmic decrements already defined for equation (11)

$$I_r = E \frac{\lambda}{2uL} \cdot \frac{1}{\sqrt{\delta_r(\delta_t + \delta_r)}} \quad \ldots\ldots\ldots \quad (9b)$$

* It is easily demonstrated that the effective value A of the magnitude composed of a series of damped oscillations of the type $a = A_0 \epsilon^{-\alpha t} \sin \omega t$ which succeed each other with frequency ν is expressed by $A = \frac{1}{2}\sqrt{\frac{\nu}{\alpha}} A_0$ when the frequency of oscillation $f = \omega/2\pi$ is sufficiently great in comparison with the frequency of the discharges and the logarithmic decrement $\delta = \alpha/f$ itself is sufficiently high to allow us to consider an oscillation as entirely exhausted, at the moment when the successive one begins.

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Hence, together with (7) (8) and (4) :—

$$h = \frac{I_r}{I} \cdot \frac{dL\sqrt{\delta_r(\delta_t + \delta_r)}}{2\pi\mu h_r} \quad \ldots\ldots\ldots \quad (13a)$$

$$h = \frac{I_r}{I} \cdot \frac{dL\lambda\sqrt{\delta_r(\delta_t + \delta_r)}}{4\pi^2\mu S_r \cos\alpha} \quad \ldots\ldots\ldots \quad (14a)$$

The effective height h of the sending antenna being known and I and λ measured, the radiation resistance R_i and the power radiated P_i are easily calculated by means of equation (5).

9. Influence of the Distance, Position and Form of the Two Aerials.— Up to the present it has been assumed that, in order to deduce the value of the height of radiation h from the measurements of the magnetic field H, the relations (4) were applicable. But in their turn these have been deduced on the hypothesis that the distance of the receiving aerial from the sending one was sufficiently great to render negligible the direct inductive action (of which no account is taken in equation (4)), and that therefore the Hertzianaction alone, that is to say, the phenomenon of propagation by waves, existed. It is, however, easy to calculate that, with the ordinary dimensions of aerials, direct action is practically negligible at a distance equal to λ, and that therefore it is a more than sufficient precaution to place the receiving station at distances not less than about 2λ. With sufficiently sensitive instruments available, the receiving station can be arranged even at considerably greater distances without any effects of absorption being noticeable, except in the case of special inequalities of the intervening ground.

In this way also these inequalities of the ground can give rise within the limits of distances of some wavelengths, to deformations of the wavefront, which do not allow us to consider F as vertical and H as horizontal and both as perpendicular to the line joining the transmitting and receiving aerials.

In a similar way, with the ordinary magnitude of the horizontal dimension of the closed receiving frames in comparison with the wavelength, the error depending on the imperfect coincidence of phase of the magnetic flux through the various elements of the surface of the circuit, is quite negligible.

The relations (4) are moreover based on the assumption that the sending antenna is equivalent to a half dipole of such height h that with the same λ and I it gives rise to the same radiation. This definition is not ambiguous and allows the calculation of the power radiated by equation (5), if the sending antenna radiates equally in all directions and therefore if the simple assumption can be made with respect to $\sin\theta$ where θ is the angle between the direction of propagation and the axis of the dipole. Experience has demonstrated that this condition is approximately fulfilled in the case of modern aerials with a relatively concentrated capacity, that is to say, constituted by a horizontal portion (a bundle or network of wires in the form of a triangle) or square or even of a rectangle or trapezium of not too elongated a form, and leading down wires connected with the centre or with one of the sides or vertices of the horizontal part. In the case of the Marconi type of bent aerials, on the contrary, with a great horizontal development, or of other

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types of directive aerials, the radiation does not take place equally in the various directions of the horizon, so that the measurements must be repeated in several sectors. To the results of each one of such measurements we can still apply equations (13) and (14), deducing the corresponding effective height h, but since the latter varies from one sector to the other, we cannot utilise (5) directly in order to deduce the radiation resistance and the radiated power. On the other hand as the measurements cannot be carried out in a great number of directions both horizontally and at various inclinations, it is considered suitable to admit as an hypothesis, that in each vertical plane F and H vary proportionately to sin θ as expressed in (4). It follows from this and (5) that the element of radiation dP_i in the sector of horizontal aperture $d\alpha$ is

$$dP_i = \frac{8\pi}{3}\sqrt{\frac{\bar{\mu}}{\epsilon}}\left(\frac{h}{\lambda}\right)^2 I^2 d\alpha,$$

and therefore calculating h or R_i for every sector, we get the mean value h_m or of R_{im} from the relations :

$$h_m = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} h^2 d\alpha} \quad \text{and} \quad R_{im} = \frac{1}{2\pi}\int_0^{2\pi} R_i d\alpha \quad . \quad . \quad . \quad (15)$$

which introduced in (5) in their turn allow us to estimate the radiated power P_i.

10. Influence of the Wavelength.—In the case of the half Hertzian dipole (to which equations (4) refer), the height h is a well-defined geometrical dimension, independent of the oscillations which are generated in it. On the contrary, in the case of ordinary aerials, it must be pointed out that the radiation height h, defined precisely as the height of the equivalent dipole, depends on the distribution of the current in the aerial, and therefore also on the wavelength used. In fact, even limiting ourselves to the consideration of the case of an aerial with negligible horizontal dimensions as compared with λ and without any directive properties, it is necessary to apply (4) to each element of height dh and therefore to substitute for the product Ih the integral $\int_0^{h'} I_h dh$ extended to the whole geometric height h' of the aerial.*

It follows that the effective height which is defined precisely by

$$Ih = \int_0^{h'} I_h dh \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

depends on the law of distribution of $I_h = f(h)$, which in its turn depends in general on the wavelength. This is easily found for a simple vertical aerial (Fig. 4), for which it has already been mentioned (par. 4) how in the case of oscillation with the natural wavelength the distribution of the capacity and of the self-inductance along the conductor being assumed uniform, we get

* It is understood that if between two horizontal planes placed at a distance dh one from the other, there are included several conductors belonging to the aerial, I_h must be put equal to Σ (I), adding algebraically the values of the current in each of the single conductors.

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$h = \frac{2}{\pi} h'$ because $I_h = I \cos \frac{\pi}{2} \cdot \frac{h}{h'}$. Now, when in the place of the natural oscillation λ_0 one produces an oscillation (for example by inserting between the base of the aerial and the earth a self-inductance L) of a greater wavelength λ, the distribution of I_h is represented by :

$$I_h = I \frac{\sin \frac{\pi}{2} \frac{\lambda_0}{\lambda} \frac{h' - h}{h'}}{\sin \frac{\pi}{2} \frac{\lambda_0}{\lambda}} \quad \ldots\ldots\ldots \quad (17)$$

from which with (16) the effective height

$$h = \frac{2}{\pi} h' \frac{\frac{\lambda}{\lambda_0} \left(1 - \cos \frac{\pi}{2} \frac{\lambda_0}{\lambda}\right)}{\sin \frac{\pi}{2} \frac{\lambda_0}{\lambda}} \quad \ldots\ldots\ldots \quad (18)$$

is deduced, which includes as a particular case for $\lambda = \lambda_0$ the effective height $\frac{2}{\pi} h'$, and gives ever decreasing values of h as λ increases, reaching its minimum value $h'/2$ for the case of $\lambda_0 << \lambda$.*

It is seen, therefore, that while in the half dipole the effective height is constant as λ varies, and is equal to the geometric height h, in the linear half oscillator it progressively decreases as λ increases from $0{\cdot}64h$ to $0{\cdot}50h$. In aerials of the ordinary type, generally something intermediate takes place, because in them the designer tries to concentrate the capacity in one more or less horizontal part placed as high as possible, whereas the inductance is provided mainly by the lead-down or tail, which connects that capacity with the earth through the exciting appliances or receivers. However, the conditions of the half dipole cannot be realised in connection with the relation between the effective height h and the maximum geometric height of the aerial h', and this owing to the effect both of the sag of the conductors constituting the upper network, as well as of the capacity inevitably distributed also along the down-leads, and finally on account of the causes of local absorption (par. **11**). Therefore, as a general rule, values of h/h' which vary between $0{\cdot}6$ and $0{\cdot}7$ are found for non-directive aerials.

As to the variation with the wavelength, it is generally very small owing to the fact that generally considerably greater wavelengths are used than the natural one for which even in the case of a linear aerial the variations of h with those of λ are very small.

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* The discussion of the formulæ can be extended even to the case in which an oscillation is produced with a wavelength $\lambda < \lambda_0$ (for example by inserting a capacity at the base of the aerial). In this case values of h increasing as λ decreases are calculated up to values which may turn out very great when λ approaches $\lambda_0/2$. Nor must this appear strange when we remember that in this case the current I at earth connections is no longer the maximum effective value which is found along the aerial, because the curve of the current is displaced upwards and the value of I tends to zero (whatever may be the oscillatory power called into play) when λ approaches $\frac{\lambda_0}{2}$.

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11. Influence of the Supports of the Sending Antenna.—On the basis of what has been set forth above, the radiation height of an aerial is shown to depend on its geometric figure and to a small extent also on the wavelength of the oscillation of which it is the source. In reality another important element appreciably affects the value of the height h, as calculated by (13) and (14) on the basis of measurements executed at a certain distance, d. This arises through all those causes, which give rise, through the earth connection, to the passage of currents which although contributing to the value of I measured and introduced in the formulæ, do not, however, contribute to the radiation. These causes lie in all the local circuits in which the aerial oscillation acting by direct induction (electrostatic or electromagnetic) induces other secondary oscillations which always present a component in opposition of phase and therefore attenuate the action at a distance, or which comes to the same thing, reduce the effective height. Among such local circuits, which are represented by every more or less conductive material situated in the field of the aerial, the mast structures and their stays take the foremost place. The power which they absorb depends on their shape, on their position with respect to the aerial and on their electrical resistance. To reduce these losses recourse is had in varying measure, to subdividing the conducting bodies (and especially the stays) by interposing insulators, to the separation of the metal structures from earth by basal insulators, to the more or less partial use of wood instead of iron, to a suitable examination of the reciprocal position of the aerial and its supports, to the elimination as far as possible of conducting masses from the proximity of the aerial circuit and so on. Another cause of the increase of the current I without a corresponding increase of radiation may arise through the presence of capacities between the lowest portion of the aerial down-leads and the earth due to their passage through the walls of the buildings, and to the supporting and holding insulators.

In connection with the phenomena just mentioned, many experiments have demonstrated for example, that substituting continuous stays for stays subdivided by insulators, stretching metal conductors along wooden supports, or connecting to earth metallic supports, which were previously insulated, we can indeed get an increase of the current I in the sending antenna (at equal excitation), but there is also such a considerable decrease of h, that usually the radiated power is reduced. Especially in the case of metal masts previously insulated from the ground and then connected to it through a variable resistance, it is found that there is in general a critical value of such a resistance, with which the unfavourable action from the point of view of radiation, attains a maximum. Systematic experiments are in progress for the deduction of rational criteria for the insulation of the base of masts and for the distribution of insulators along the stays.*

(To be concluded.)

* Quite apart from what has been stated in this note, the question of the radiation from aircraft aerials or from aerials placed on the ground, on the water, or actually immersed to a certain depth, deserves a separate study. These types of aerials are found in conditions remarkably different to those considered for ordinary aerials.

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The Effect of Modulation Waveshape upon Received Signals.*

By A. S. BLATTERMAN

(*Radio Engineer, Signal Corps, U.S. Army*).

There are several waveshapes of modulation employed in radio communication. For example, we have the logarithmic modulation of spark transmitters as in Fig. 1 (a), the chopped modulation of chopper sent continuous waves (Fig. 1 (b)), sine modulation as produced by a pure tone on a radio telephone transmitter (Fig. 1 (c)), or interrupted sine modulation (Fig. 1 (d)), as obtained from continuous wave transmitters using A.C. plate voltages, etc.

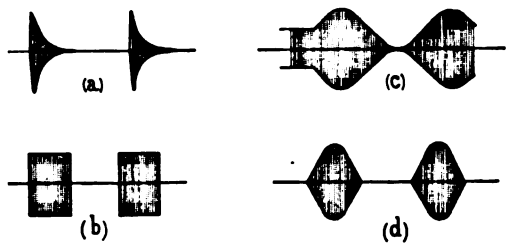

FIG. 1.

Not all of these modulation waveshapes are equally effective. If, in each case, the R.M.S. current in the transmitting antenna is the same, it will be found that the strength of signal received at a distance favours certain of these modulations over others. Distortion is also important, and more pronounced with some kinds of modulation than others. It is the purpose of the present paper to indicate the extent of these distortions and to give first an approximate comparison and later a more accurate, although somewhat more cumbersome, method for comparing the signal strength produced by various waveshapes of modulation with given R.M.S. antenna current at the transmitter.

NATURE OF THE DISTORTION EFFECT.

A qualitative understanding of the distortion effect may be clearly had by calling attention to the well-known difference between the envelope curves of oscillating current in primary and secondary of a pair of coupled spark excited circuits, and the rectified audio frequency telephone current in the detector of a receiving circuit. As is well known, a spark discharge in the primary of a pair of tuned circuits very loosely coupled gives current oscillations which can be represented by the curve of Fig. 2 (a), while in the secondary the current oscillation follows more nearly a curve like that of Fig. 2 (b).

* Received November 18th, 1920.

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The two circuits may be thought of as the transmitting and receiving antennas respectively, and it becomes evident at once that the envelope curve of the received current is not at all a replica of that transmitted. The detector at the receiver produces a further change in waveshape owing to its non-linear rectification characteristic so that the sound ultimately produced in the telephone receivers, while characteristic of the transmitted spark note, is not by any means an exact reproduction of it.

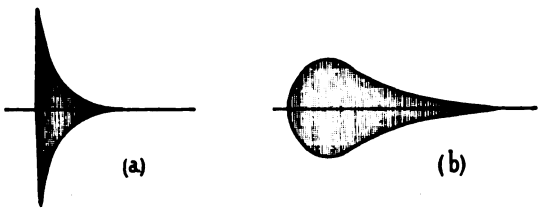

FIG. 2.

A quantitative estimate of the distortion effect attributable to the detector may be readily obtained by consideration of the change in waveshape of a pure sinusoidally modulated oscillation applied to the detector. Such an oscillation is represented in Fig. 3; and its equation is—

$$e = A \sin \omega t + B \sin pt \sin \omega t \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

p being the modulating audio frequency periodicity and ω the carrier radio frequency periodicity. The detector characteristic, Fig. 4, can be represented by the equation

$$i = a_1 e + a_2 e^2 + \ldots \ldots \ldots \ldots \ldots \quad (2)$$

in which terms of higher order than the second may be neglected with most

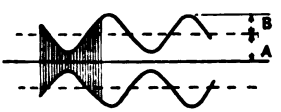

FIG. 3.

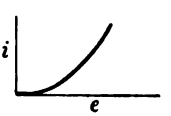

FIG. 4.

forms of detectors in common use. If the value of e from (1) is substituted in (2) the detected current becomes

$$i = \frac{a_2}{2}\left(A^2 + 2AB \sin pt + \frac{B^2}{2} - \frac{B^2}{2} \cos 2\,pt\right) + \text{Radio frequency terms}. \quad (3)$$

It is seen that a term of double frequency with amplitude $\frac{B^2}{2}$ has been introduced by the action of the detector. This term produces distortion and the waveshape changes from the original sine wave of modulation to something resembling the heavy line of Fig. 5.

In order to illustrate the distortion which occurs in the tuned radio

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frequency receiving circuits we may again take the relatively simple case of a sinusoidally modulated transmission of the type shown in Fig. 3. This, it will be observed, is now supposed to be the current in the transmitting antenna. The equation is of the form of (1).

$$i_s = A_s \sin \omega t + B_s \sin pt \sin \omega t \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

The instantaneous electromotive force produced by this current in a distant receiving antenna will be

$$e_r = ki_s = k\,(A_s \sin \omega t + B_s \sin pt \sin \omega t) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

This may be written

$$e_r = k\left\{A_s \sin \omega t + \frac{B_s}{2} \cos\,(\omega - p)t - \frac{B_s}{2} \cos\,(\omega + p)t\right\} \quad . \quad . \quad . \quad (6)$$

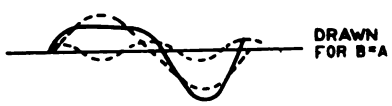

FIG. 5.

showing that the received voltage comprises components having three different radio periodicities, the carrier ω, one higher $(\omega + p)$ and one lower $(\omega - p)$. The receiving circuits are tuned to the carrier frequency ω and the two side frequencies corresponding to $(\omega + p)$ and $(\omega - p)$ are therefore off tune. Each of the component voltages present will force current through the circuit and the total current will thus be the sum of three components having the different frequencies of the driving E.M.F.'s. The tuned component (ω) will experience impedance which is entirely resistive. The side frequency components find impedances involving not only the resistance of the receiving antenna but also some reactance. The side frequency of higher frequency will be retarded in phase while the lower side frequency will be advanced. The current equation thus becomes

$$i_r = k\left\{\frac{A_s}{r_r} \sin \omega t + \frac{B_s}{2Z_r'} \cos\,[(\omega - p)t + \phi'] - \right.$$
$$\left. - \frac{B_s}{2Z_r''} \cos\,[(\omega + p)t - \phi'']\right\} \quad . \quad (7)$$

where

$$\phi' = \cos^{-1} \frac{r_r}{Z_r'},$$

$$\phi'' = \cos^{-1} \frac{r_r}{Z_r''}$$

$$Z_r' = \frac{1}{\sqrt{r_r^2 + \left[(\omega - p)L - \frac{1}{(\omega - p)C}\right]^2}}$$

$$Z_r'' = \frac{1}{\sqrt{r_r^2 + \left[(\omega + p)L - \frac{1}{(\omega + p)C}\right]^2}}$$

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r_r = resistance of receiving antenna.
L = inductance ,, ,,
C = capacity ,, ,,

If the expressions for Z' and Z'' are expanded and the approximation used that

$$\frac{1}{1 \pm \frac{p}{\omega}} = 1 \mp \frac{p}{\omega}$$

it is seen that

$$Z_r' = Z_r'' = Z'$$
$$= \sqrt{r_r^2 + 4p^2L^2}$$
$$\phi' = \phi'' = \phi$$
$$= \cos^{-1} \frac{1}{\sqrt{1 + \frac{4p^2L^2}{r_r^2}}}$$
$$= \cos^{-1} \frac{1}{\sqrt{1 + \frac{4p^2}{\omega^2} \cdot \frac{\pi^2}{\delta_r^2}}}$$

where δ_r = decrement of receiving circuit. Equation (7) for the received current now takes the simpler form

$$i_r = \frac{k}{r_r} \left\{ A_s \sin \omega t + \left(\frac{B_s}{2} \cos \phi\right) \cos [(\omega - p)t + \phi] - \right.$$
$$\left. - \left(\frac{B_s}{2} \cos \phi\right) \cos [(\omega + p)t - \phi] \right\}$$
$$= \frac{k}{r_r} \left\{ A_s \sin \omega t + [B_s \cos \phi] \sin (pt - \phi) \sin \omega t \right\} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

By comparison of this equation with (5) for the transmitted current it is seen that the received current is similar in form but is modulated to a lesser extent than that transmitted, by the factor $\cos \phi$. The phase of the modulation is also retarded at the receiver by angle ϕ. It is evident that if the modulation at the transmitter were not sinusoidal as in the case just discussed but of irregular waveshape as generally occurs in practice, each of the harmonics of the irregular wave would undergo a different relative change in amplitude and a different phase shift upon being established in a receiving antenna. This obviously would produce distortion, and also affect the strength of signal.

In order to indicate the magnitude of the effect Table I. has been calculated for 1,000 cycle sine modulation of a 600 metre wave with different receiver decrements. It is seen that if a receiving circuit with decrement $\delta_r = 0{\cdot}02$ is used to receive this wave the modulation will only be 85 per

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cent. of that at the distant transmitter. The result is shown graphically for 100 per cent. transmitter modulation in Fig. 6.

TABLE I.

δ_r	cos ϕ
0 005	0·369
0·01	0·62
0·02	0·85
0·04	0·955
0·10	0·99

STRENGTH OF SIGNAL.

Approximate Method.

It has frequently been shown that the detecting current for spark signals on a non-oscillating detector is proportional to the square of the R.M.S. received antenna current. A spark signal is a completely modulated wave, that is the oscillation current comes to zero for a certain portion of the audio

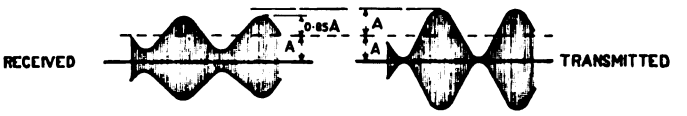

FIG. 6.

frequency cycle. After proving that this relation between detecting current and mean square antenna current holds good also in the case of pure sine modulation provided the modulation is complete, and calculating the deviation from this proportionality when the modulation is not complete, it will be assumed that the mean square received antenna current may be taken as a basis for comparison of all waveshapes of modulation. A direct comparison of the antenna currents squared will be used in all cases where the envelope modulation curve comes to zero during the audio cycle, that is complete modulation, and when the modulation is incomplete a correction factor will be applied.

Sine Modulation.

The detecting current in this case can be readily calculated with accuracy, and it is now desired to compare its actual value with that figured from the square of the R.M.S. antenna current. The received current and the detector voltage * have the forms

$$i = A \sin \omega t + B \sin pt \sin \omega t \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

$$e \cong mi = mA \sin \omega t + mB \sin pt \sin \omega t \quad . \quad . \quad . \quad . \quad . \quad (10)$$

* See p. 151, last paragraph.

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The detector voltage (10) gives in the telephone circuit detecting current

$$i_d = \frac{a_2 m^2}{2}\left(A^2 + 2AB\sin pt + \frac{B^2}{2} - \frac{B^2}{2}\cos 2pt\right) + \text{radio frequency terms}$$

as was shown above (equation (3)). Of this the audio frequency signal component is

$$i_a = \frac{a_2 m^2}{2}\left(2AB\sin pt - \frac{B^2}{2}\cos 2pt\right)$$

The effective value of this is

$$_aI_{\text{eff.}} = \frac{a_2 m^2 B}{\sqrt{2}}\sqrt{A^2 + \frac{B^2}{16}} \quad \ldots\ldots\ldots (11)$$

It is to be noted that in this calculation the terms of higher order than the second in equation (2) for the detector characteristic have been neglected so that actually the value of $_aI_{\text{eff.}}$ will be slightly larger than that given by (11).

Using the mean square antenna current as basis for calculation of detecting current we use the impressed voltage (10) and detection factor a_2 and obtain

$$_aI'_{\text{eff.}} = a_2 E^2_{\text{eff.}} = a_2 m^2 \frac{A^2}{2}\left(1 + \frac{B^2}{2A^2}\right) \quad \ldots\ldots\ldots (12)$$

Letting $K = \frac{B}{A}$ = percentage modulation of received antenna current, we thus find the ratio of actual detecting current (11) to the value calculated from mean square antenna current (12) as

$$\sigma = \frac{_aI_{\text{eff.}}}{_aI'_{\text{eff.}}} = \frac{\sqrt{2}\,K\sqrt{1 + K^2/16}}{1 + \frac{K^2}{2}} \quad \ldots\ldots\ldots (13)$$

The value of this ratio is drawn for different values of K in Fig. 7 where it is seen that for $K = 1$, *i.e.*, complete modulation, σ is practically unity,* although when the modulation is not complete ($K < 1$) the ratio quickly decreases. This means that for cases where complete modulation is obtained comparison of detected currents can be made directly by comparison of mean square received antenna currents, but for incomplete modulation the antenna current squared must be multiplied by a correction factor as given by (13) or Fig. 7, in order to get figures for comparison of signal strength.

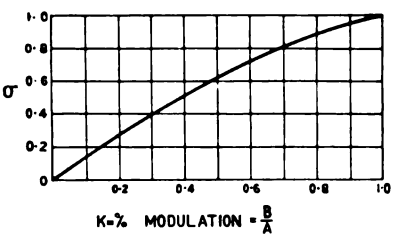

FIG. 7.

* It would probably be exactly unity if the higher order terms of the detector equation had not been ignored.

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THE GENERAL CASE.

Whatever the modulation wave-form of transmitting antenna current, *i.e.*, logarithmic as in spark transmission, sinusoidal, chopped, telephonic, etc., it can in general be represented by the expression :

$$i_s = {}_sI_0\left\{\begin{array}{r} S_0 + S_1 \sin(pt + {}_s\theta_1) + S_2 \sin(2pt + {}_s\theta_2) + \\ + S_3 \sin(3pt + {}_s\theta_3) + \ldots . \end{array}\right\} \sin \omega t \quad . \quad . \quad (14)$$

The bracketed expression being the Fourier sines representative of the envelope curve of modulation and ${}_sI_0$ being the maximum value of this curve. See Fig. 8.

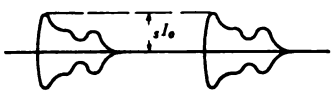

FIG. 8.

The problem is to determine the effect of different modulation waveshapes at the transmitter upon signal strength and quality, the R.M.S. current in the sending antenna being the same in all cases.

The R.M.S. transmitting antenna current is obtained from (14) as

$${}_sI_s = {}_sI_0\sqrt{\frac{S_0^2}{2} + \frac{S_1^2}{4} + \frac{S_2^2}{4} + \frac{S_3^2}{4} + \ldots .} \quad . \quad . \quad . \quad . \quad . \quad (15)$$

Equation (14) can be re-written in the form

$${}_si = {}_sI_0\left\{\begin{array}{r} S_0 \sin \omega t + \frac{S_1}{2}\cos[(\omega - p)t - \theta_1] - \frac{S_1}{2}\cos[(\omega + p)t + \theta_1] + \\ + \frac{S_2}{2}\cos[(\omega - 2p)t - \theta_2] - \frac{S_2}{2}\cos[(\omega + 2p)t + \theta_2] + \\ + \ldots . \end{array}\right\}$$

This equation shows the sending current to be made up of numerous constituents comprising a carrier frequency ω and side frequencies above and below this respectively with values

$$\omega \pm p_1 \quad \omega \pm 2p_1 \quad \omega \pm 3p_1 \ldots .$$

The receiving antenna being tuned to the carrier frequency ω tends more or less to suppress the side frequencies and also causes changes in phase, as was explained above in connection with equation (7). The received current becomes, with these circumstances in view,

$${}_ri = \frac{k\,{}_sI_0}{r_r}\left\{\begin{array}{r} S_0 \sin \omega t + \frac{S_1}{2}\cos\phi_1\cos[(\omega - p)t - \theta_1 + \phi_1] - \\ - \frac{S_1}{2}\cos\phi_1\cos[(\omega + p)t + \theta_1 - \phi_1] + \\ + \frac{S_2}{2}\cos\phi_2\cos[(\omega - 2p)t - \theta_2 + \phi_2] - \\ - \frac{S_2}{2}\cos\phi_2\cos[(\omega + 2p)t + \theta_2 - \phi_2] + \\ + \ldots . \end{array}\right\} \quad . \quad . \quad (16a)$$

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$$= \frac{k\,{}_sI_0}{r_r}\left\{\begin{array}{r} S_0 + [S_1\cos\phi_1]\sin(pt - \phi_1 + \theta_1) + \\ + [S_2\cos\phi_2]\sin(2pt - \phi_2 + \theta_2) + \\ + [S_3\cos\phi_3]\sin(3pt - \phi_3 + \theta_3) + \\ + \ldots . \end{array}\right\}\sin\omega t \quad \ldots . \quad (16b)$$

where $$\phi_n = \cos^{-1}\frac{1}{\sqrt{1 + \frac{4\pi^2}{\delta_r^2}\cdot\left(\frac{np}{\omega}\right)^2}}$$

Following the procedure indicated above we are to take the square of the effective current (16) as a measure of signal strength. This is

$${}_rI_e^2 = \frac{k^2\,{}_sI_0^2}{r_r^2}\left\{\frac{S_0^2}{2} + \frac{S_1^2\cos^2\phi_1}{4} + \frac{S_2^2\cos^2\phi_2}{4} + \frac{S_3^2\cos^2\phi_3}{4} + \ldots .\right\} \quad (17)$$

which with the help of (15) becomes

$${}_rI_e^2 = \frac{k^2\,{}_sI_0^2}{r_r^2}\left\{\frac{\frac{S_0^2}{2} + \frac{S_1^2\cos^2\phi_1}{4} + \frac{S_2^2\cos^2\phi_2}{4} + \frac{S_3^2\cos^2\phi_3}{4} + \ldots .}{\frac{S_0^2}{2} + \frac{S_1^2}{4} + \frac{S_2^2}{4} + \frac{S_3^2}{4} + \ldots .}\right\} \quad (18)$$

$$= \text{Constant} \times \left\{\frac{\frac{S_0^2}{2} + \frac{S_1^2\cos^2\phi_1}{4} + \frac{S_2^2\cos\phi_2}{4} + \ldots .}{\frac{S_0^2}{2} + \frac{S_1^2}{4} + \frac{S_2^2}{4} + \frac{S_3^2}{4} + \ldots .}\right\} \quad \ldots . \quad (19)$$

For different modulations giving correspondingly different values of S_0, S_1, S_2, S_3 . . ., ϕ_1, ϕ_2, ϕ_3 . . . , we therefore compare terms of the form of the term of (19) within brackets in order to determine relative signal strengths. Several concrete cases of importance as arising in practice will now be compared in this way.

It should be noted that the impressed detector voltage originating across the tuning condenser is, from (16a),

$$e = \frac{k\,{}_sI_0}{r_r}\left\{\begin{array}{r} \frac{S_0}{\omega C}\sin(\omega t + 90°) + \frac{[S_1\cos\phi_1]}{2(\omega - p)}\cos[(\omega - p)t - \theta_1 + \\ + \phi_1 + 90°] - \frac{[S_1\cos\phi_1]}{2\omega + p)}\cos[(\omega + p)t + \\ + \theta_1 - \phi_1 + 90°] + \ldots . \end{array}\right\} . \quad (16c)$$

and since p, $2p$, $3p$, $4p$, etc. are very small compared with ω the expression becomes practically identical in form with the current (16a) and (16b), that is, the relative amplitude of the several harmonic constituents of the envelope curve is the same for the detector voltage as for the received current.

(To be concluded.)

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The Physical Society's Exhibition.

A Description of the Exhibits (*continued from page 97*).

MR. J. ST. VINCENT PLETTS exhibited his new pattern of slide rule, now known as the "Davis-Pletts Slide Rule."

This slide rule has (besides a number of minor modifications) two novel features, which greatly extend the usefulness of the instrument for dealing with the mathematical functions so often met with in radio and other physical problems. In the majority of the slide rules now on the market that are provided with log-log scales, the scale is non-recurring and is usually made two or three times the length of the rule so that confusion often arises as to what part of the scale is being used. In the Pletts rule the range of the log-log scale is indefinitely extended by making use of the properties of the characteristics and mantissæ of common logarithms to base 10. Fig. 4 shows the general arrangement of the scales on the rule and on the back of the slide. The common logarithms can thus be read directly from these scales, all that is necessary being to add the appropriate characteristic. If it be desired to raise any number to any power one proceeds in the usual way, but if the result is greater than 10 the other end of the slide can be used, and the decimal point moved correspondingly. A second novel feature is the provision on the slide of scales for all the ordinary exponential, circular and hyperbolic functions, arranged to read on the same log scale, so that the product or ratio of any such functions can easily be obtained. Along the front of the slide an equally divided scale is arranged to give $a\epsilon^x$, ϵ^a and $\log ax$. In combination with the scales on the back of the slide all such functions as $\epsilon^n \sin x$, and $\log n \cosh x$ can be obtained with a single setting of the slide and cursor, while every combination of the various functions is obtainable with two or more settings.

(*To be continued.*)

Notes.

Personal.

Dr. J. Zenneck, Professor of Experimental Physics at the Technische Hochschule at Munich, has been elected a member of the Bavarian Academy of Learning. **[2006]**

Frank Conrad, Consulting Engineer to the Westinghouse Electric and Manufacturing Co., of East Pittsburgh, U.S.A., has been appointed Assistant Chief Engineer to that company. Mr. Conrad has been connected with the Westinghouse Co. for almost thirty years. The aircraft radio apparatus developed to the designs of Mr. Conrad during the war, was the only U.S. equipment of its kind which reached France in any quantity. **[2168]**

M. Léon Bouthillon has been awarded the Hebert prize by the Paris Academy of Sciences for his work and publications on wireless telegraphy. **[2109]**

The Edison medal for the year 1920 has been awarded by the American Institute of Electrical Engineers to Mr. M. I. Pupin for his physical and mathematical work. This medal is awarded annually for the best work of an electrical nature whether of technical or industrial application. **[2071]**

Commercial.

A NEW THREE-ELECTRODE VALVE.—The Radio Corporation of America announces the introduction of a new pattern of three-electrode vacuum tube, designated Radiotron U.V. 200,

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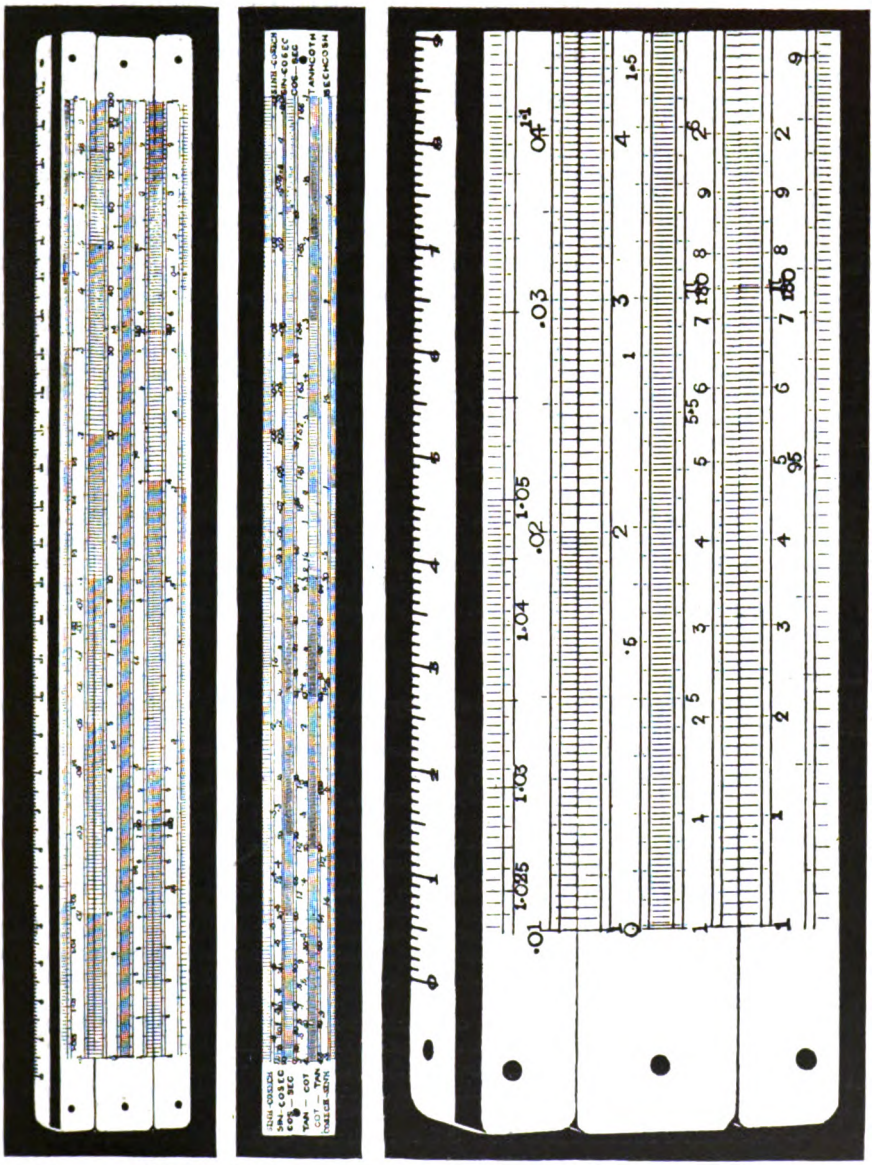

FIG. 4.—The "Davis-Pletts" Slide Rule, showing front view of rule, and back of slide; also an enlarged view of part of the rule.

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which is specially designed for the use of wireless amateurs and experimenters. The new tube is not of the extremely "hard" variety, and is consequently best suited for a low value of plate voltage (about 18 volts usually), and makes a good detecting valve. The best values of the grid condenser and leak are stated to be about 0·00025 μF and 0·5 megohm respectively. The tube is also suitable for note-magnifiers or low-frequency amplifiers, but if more than two stages are required in cascade, it is recommended that all valves after the first should be of a "harder" type—such as "Radiotron U.V. 201." [2170]

NEW WIRELESS STATIONS.—The Federal Wireless Telegraph Co., of San Francisco, has signed a contract to erect powerful wireless stations at Shanghai, Peking and Harbin at a cost of $4,200,000. It will be a joint Chino-American operation to be controlled by the Ministry of Communications; after ten years the system will revert to China. A protest has been entered against this contract on the ground that it violates one made with the English Marconi Co. (See note on page 41.) [1996]

The Australian wireless coast station at Roebourne was closed for public correspondence on February 7th, 1921. [2172]

HIGH VOLTAGE ACCUMULATORS.—In a pamphlet recently issued by the Hart Accumulator Co., Ltd., particulars are given of the high voltage accumulator units manufactured by that firm. The sets are manufactured primarily for use with thermionic valve amplifiers, although they may obviously also be employed for many electrical testing purposes. The cells are contained in waxed teak boxes, and each cell is fitted in an ebonite box of special design to ensure high insulation. The sets are made up in 50 volt units. [2171]

Messrs. Newton & Co., Ltd., have recently prepared a set of lantern slides for a lecture on "Wireless Telegraphy" dealing more particularly with the Elwell-Poulsen system. They are accompanied by a full set of notes, which provide alternative methods of treatment for audiences of varying degrees of acquaintance with the subject. Many of the slides are from hitherto unpublished photographs and we think should prove both interesting and useful to many of our readers. Messrs. Newton & Co.'s address is 37, King Street, Covent Garden, W.C. 2.

Legal.

The following changes in the existing radiotelegraph message rates and coast taxes have recently been notified:—

SWEDEN AND DENMARK: Coast tax 40 centimes per word, minimum 4 francs per radiotelegram, commencing January 1st, 1921.

NORWAY: Stations at Bergen, Flekkeroy, Sorvagen, Tjome, and Utsire, coast tax 40 centimes per word with minimum of 4 francs. Commenced January 1st, 1921.

STRAITS SETTLEMENTS: The coast tax of radio stations at Penang and Singapore was increased to 60 centimes per word on January 1st.

TRINIDAD: On and after November 30th, 1920, a charge of 4 cents per word is made to cover the cost of delivery of messages outside the town of Port of Spain.

MADAGASCAR: On October 1st last the interior tax applicable to radiotelegrams which originate in or have their destination in Madagascar (including the Comore Islands) and exchanged directly with the coast stations of Madagascar and of the Comores has been fixed at 20 centimes per word.

NEW YORK: From February 1st, the coast tax through the WNY radio station will be increased to 10 cents per word. A new station is also to be erected on Cape Cod (the sending station to be located at Marion, Mass., and the receiving station at Chatham, Mass.). It will be completed within the next month. The coast station tax will be 10 cents per word.

The rate for radio messages from U.S.A. to Great Britain *via* the transatlantic radio stations has been increased from 17 to 18 cents per word.

U.S.A.: The coast station rate of the Naval Radio Station at Norfolk, Virginia, will be increased to 10 cents per word from March 15th, 1921.

FRANCE: A charge of 6 francs for each radiogoniometric bearing taken by a French land station at the request of a ship station will be made. This tax came into force on December 1st last.

BELGIUM: The Belgian Telegraph Administration will apply a tax over the telegraph lines

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of Belgium for radiotelegrams originating in or destined for Belgium, and exchanged directly with Belgian coastal radio stations of fifteen centimes per word, with a minimum of 1 franc 50 per radiotelegram. For urgent radiotelegrams these charges will be 45 centimes, and 4 francs 50 respectively. These revised charges came into force on December 15th, 1920.

RADIO TRAFFIC ARRANGEMENTS.—From October 15th, 1920, the hours of service of the Weltvreden Radio Station (Dutch East Indies) are as follows: Weekdays, 6 a.m. to 11 p.m., Sundays and holidays, 9 a.m. to 12 noon, and 2 p.m. to 5 p.m.

The British Post Office radio station at Devizes (call letters GKU) is now open for continuous wave communication with ships, on a wavelength of 2,100 metres. The station will normally be open at all times for the receipt of messages from ships, but will as a rule only call ships during the following periods: 1 a.m. to 1.30 a.m., 5 a.m. to 5.30 a.m., 9 a.m. to 9.30 a.m., 1 p.m. to 1.30 p.m., 5 p.m. to 5.30 p.m., 9 p.m. to 9.30 p.m. G.M.T. The station will not however be available for communication during periods of three minutes commencing at 15 and 45 minutes past every hour (G.M.T.) as ships using wavelengths other than 600 metres are required during these periods to keep watch on a wavelength of 600 metres. The message rates are the same as those for messages through other British coast stations.

The radio station at Havana, Cuba (call letters PWA), will transmit daily at 12.30 a.m., 75th meridian time, (5.30 a.m. G.M.T.) long distance messages destined for vessels at sea. A wavelength of 2,150 metres is employed, and a power of 10 kW in the antenna. [2166]

General.

A NEW ARRANGEMENT OF DIRECTION FINDER.—We have received some interesting particulars of a recent patent application by Mr. F. Murphy, No. 1101/1920, which deals with improvements in direction finding. The essential idea consists in erecting a number of aerials at suitable angular displacements and supplying each aerial with high frequency oscillations which are modulated at a lower frequency, the phase of modulation for each aerial being appropriate to its angular displacement. Thus if three aerials are used displaced at angles of 120° the phase displacements of the currents supplied to modulate the radiations from these oscillations will also be 120°. The resultant effect is the production of a directional field of radiation from the combined aerials in which the direction of maximum intensity rotates at the modulation frequency. The arrangement is thus applicable for "radiophare" work, and avoids the necessity of rotating the aerial system or other parts of the apparatus. [2169]

HIGH-TENSION INSULATORS FOR SUPPORTING AERIALS.—The question of aerial insulation for high-power stations is a very difficult one and is in fact limiting the output of some well-known stations at the present time. Hitherto it has been necessary to employ strings of eight or ten ordinary suspension type insulators as used on transmission lines. At wireless frequencies these have quite an appreciable capacity, and when broken up after having been in service, a blue discoloration can be seen right through the porcelain as a result of the passage of charging current. The voltage distribution for the string is of course not uniform and there are frequent breakdowns. It is interesting therefore to have some particulars of a new insulator which is being put into use at the G.P.O. stations at Abu Zabal, Leafield and Northolt, and which promises to solve this important problem. These insulators consist of porcelain rods or tubes up to 5 feet in length and having a diameter of about 4 inches. They are held in tension; their electrostatic capacity is therefore extremely small. Their flash over voltage is beyond the capacity of any testing transformers at present available, even under standard rain tests with a precipitation of 1 inch of rain in five minutes on the insulator. Flux distributing rings of about 21 inches diameter are fitted on the aerial end of the insulators and porcelain drip rings are cemented to the porcelain to break up the flow of very heavy rain.

In addition their weight is less than the equivalent of ordinary insulators, and their cost is also lower. The use of porcelain in tension is of course an unusual step, but we understand that a number of such insulators have been in use at various places, and those at present being made for the G.P.O. are being tested with a load of 10,000 lbs. before being put into service. Such a test demands a very high grade of porcelain with an entire absence of flaws and departure from the straight. They are being manufactured by Messrs. Bullers, Ltd., of Hanley, Staffs.

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Review of Radio Literature.

1. Abstracts of Articles and Patents.

Radio Stations and Installations (General and Descriptive Articles).

1542. The Inauguration of the Paris Radio Central. (*Radioélectricité*, 1, pp. 369—377, January, 1921.)

Describes the ceremony of the laying of the foundation-stone of the new Radio Central near Paris on January 9th, 1921. The texts of the inaugural speeches are given. (See also pp. 125—133 in this issue.)

1543. The Role of the Paris Radio Central. (*Radioélectricité*, 1, pp. 378—392, January, 1921.)

This article outlines the insufficiency of French cable communications, the inadequacy of the existing radio stations to cope with all the available traffic and the need for further high-power stations. A number of illustrations are given of French high-power stations, and also of the works wherein the various parts (high-frequency alternators, etc.) are manufactured. (See also pp. 125—133 in this issue.)

1544. The Large French Radio Centre. (*Radioélectricité*, 1, pp. 393—403, January, 1921.)

Many details are given of the proposed high-power radio station for Paris. (See preceding abstracts, and pp. 125—133 in this issue.) A double-page sketch-view is included indicating the probable appearance of the completed stations.

1545. The Inauguration of the London-Paris Radio Service. (*Radioélectricité*, 1, pp. 404—408, January, 1921.)

See p. 133 in this issue.

1546. **H. Thurn.** The Wireless Installation on the *Imperator*. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 480, June, 1920. Abstracted from *Elektrotechnik und Machinenbau*, 32, p. 251, 1914.)

1547. German Wireless Network. (*Telegraphen- und Fernsprech-Technik*, 9, p. 149, December, 1920.)

An official account of the recent developments in the wireless network which is being developed throughout Germany by the postal authorities. Successful tests with high-speed automatic systems having been made, this will now be introduced in several of the stations.

1548. **H. de Gallaix.** New Radio Station at Lyons, France. (*Radio Amateur News*, 1, pp. 464—465, March, 1920.)

A general description of the station is given.

1549. **A. Gradenwitz.** New Facts about the Nauen Station. (*Radio Amateur News*, 1, pp. 560—561, April, 1920.)

1550. **A. F. Wallis.** The Otto Cliffs Naval Receiving Station. (*Radio News*, 2, pp. 6—7, July, 1920.)

An illustrated description.

1551. **R. Wilhelme.** Radio in Germany. (*Radio News*, 2, p. 8, July, 1920.)

1552. **A. H. Lynch.** An Amateur Station operated on a Commercial Scale. (*Radio News*, 2, pp. 143, 170—174, September, 1920.)

A description of the installation at the offices of the *New York Times*.

1553. Belmar Wireless Station. (*Radio Nieuws*, 3, pp. 226—228, August, 1920.)

A brief description of this station.

1554. Dual System of Radio on Pacific Ships. (*Wireless Age*, 8, p. 8, October, 1920.)

Reference is made to the installation of combined radiotelegraph and telephone instruments on a number of Pacific vessels having contracts with the **Radio Corporation of America.**

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1555. A Wireless Outfit for Small Vessels. (*Electrical Review*, 87, pp. 413—414, September 24th, 1920.)
A short illustrated description of a ship's cabinet wireless installation manufactured by Messrs. Siemens Brothers and Company, Woolwich.

1556. Japanese Radio Apparatus. (*Radio News*, 2, p. 72, August, 1920.)

1557. **A. J. Hall.** Radio in Modern Aircraft. (*Radio Amateur News*, 1, p. 539, April, 1920.)

1558. Pedal-driven Wireless Sets. (*La Nature*, 48(1), pp. 353—354, June 26th, 1920. *Technical Review*, 6, p. 788, September 28th, 1920—Abstract.)
Different arrangements of small generators attached to a bicycle frame are described and illustrated for use in connection with small trench wireless sets.

1559. **J. J. Graf.** Radio Communication to and from Trains. (*Radio Amateur News*, 1, pp. 398—399, February, 1920.)
Some of the apparatus used is described and illustrated.

1560. **W. J. Henry.** The Priess Loop Set: III. Receiver. (*Radio Amateur News*, 1, p. 406, February, 1920; p. 502, April, 1920, and p. 610, May, 1920.)

1561. **E. Nesper.** The Progress and Development of Wireless in the World War. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 486, June, 1920. Abstracted from *Elektrotechnik und Machinenbau*, 37, pp. 137—152, 1919.)

1562. **E. J. Nally.** Review of Radiotelegraphy. (*Telegraph and Telephone Age*, 38, pp. 648—649, December 16th, 1920.)

1563. The French Colonial Radio Stations. (*La Nature*, 48 (2), Supplement pp. 169—170, November 27th, 1920.)
Short notes with regard to the construction of the colonial stations.

1564. Wireless Telegraphy in China. (*Electrical Review*, 87, p. 80, July 16th, 1920.)
A note with regard to new stations to be erected.

1565. New Poulsen Radio Station. (*Telegraph and Telephone Age*, 38, p. 553, October 16th, 1920.)
Reference is made to plans for the erection of a new radio station at Oregon by the Federal Telegraph Company (U.S.A.).

1566. Combined Wire and Wireless Telephones. (*Electrical Review*, 87, p. 274, August 27th, 1920.)
A note with regard to the linking of landline and wireless telephones *via* the Air Ministry's radio station at Croydon.

1567. New York Radio Central Station. (*Wireless Age*, 7, pp. 10—12, August, 1920. *Elektrotechnische Zeitschrift*, 41, p. 867, October, 1920—Abstract. *Electrical Review*, 87, pp. 478—479, October 8th, 1920.)
Further particulars are given with a bird's-eye view plan of the site for the large radio station to be erected on Long Island.*

1568. Thousand Word a Minute World Wide Radio Station. (*Wireless Age*, 7, p. 7, July, 1920. *Technical Review*, 7, p. 30, October 12th, 1920—Abstract.)
Further particulars of the station referred to in RADIO REVIEW Abstract No. 1300, December, 1920.

Spark Transmitting Apparatus.

1569. **C. F. Cairnes.** Comparative Efficiency of High and Low Spark Frequencies. (*Everyday Engineering Magazine*, 9, pp. 61—62, April, 1920.)
Some results of test measurements are given.

1570. Design Features of the S.C.R. 112. (*Everyday Engineering Magazine*, 9, pp. 68—86, April, 1920.)
An illustrated description of a portable buzzer transmitter.

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* See RADIO REVIEW Abstract No. 1300, December, 1920.

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1571. Radio Equipment for Small Boats. (*Everyday Engineering Magazine*, 9, pp. 348—350, July, 1920.)
Installations manufactured by the **Wireless Speciality Company**, by **Cutting and Washington Radio Corporation** and by the **Radio Corporation of America** are described and illustrated.

1572. A New Hytone Transmitter. (*Everyday Engineering Magazine*, 9, p. 352, July, 1920.)
A short illustrated description of a ½ kW transmitter manufactured by the **Clapp-Eastham Company.**

1573. **Gesellschaft für drahtlose Telegraphie.** Quenched Spark Transmitter. (*German Patent*, 308422, March 7th, 1917, relating to Patent 298451. Patent granted September 6th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 90—91, January, 1920—Abstract.)
A method of producing a pure spark note in the ordinary type of quenched spark transmitter with A.C. supply by the introduction of a subsidiary alternating current of higher period in the supply circuit.

1574. **M. Deutsch.** Spark Transmitter. (*French Patent* 494019, December 20th, 1918. Published August 28th, 1919.)
The apparatus for producing high-frequency oscillations is of the kind comprising a make and break device shunted by an oscillatory circuit. A tap connection is provided to an intermediate point of an electro-magnet coil, so that when an alternating current supply is used only part of the coil is in circuit.*

1575. **D. R. Clemons.** Description and Design of a Small Transmitting Unit. (*Wireless Age*, 8, pp. 25—27, October, 1920.)
A panel type of apparatus is described using a buzzer for excitation.

1576. **E. T. Jones.** A Low Power Tuned Transmitter for Local Use. (*Wireless Age*, 7, p. 26, March, 1920.)
A simple form of tuned buzzer transmitter is described.

1577. **J. Pignone.** A Low Power Set. (*Wireless Age*, 7, pp. 41—43, June, 1920.)
A panel type of set is described and illustrated.

1578. **Société Française Radio-Électrique.** Continuous Wave Transmitter. (*French Patent* 502323, June 25th, 1915. Published May 11th, 1920.)
The invention comprises two spark gaps connected in series. Each spark gap is formed by a tube and a disc disposed eccentrically therein at one end. The tubes are arranged on a common axis and are connected to an air-blower and similarly the two discs are mounted on a common axis. The discs are moved in an epicycloidal path about the common axis of the tube.

1579. **J. Bethenod and E. Girardeau.** Improvements in Spark Gaps for Radiotelegraphy. (*French Patent* 476324, October 15th, 1914. *La T.S.F. Moderne*, 1, pp. 279—281, November, 1920—Abstract.)
This specification describes arrangements for operating spark gaps in parallel, the discharge currents being divided equally between them by means of the reactions between appropriate coupling coils joined in series with each spark gap.

Arc Apparatus.

1580. **C. Lorenz Aktien-Gesellschaft.** Oscillation Generator. (*French Patent* 504887, October 14th, 1919. Published July 19th, 1920.)
The specification refers more particularly to the production of electric oscillations by means of an electric arc and irregularities are prevented by the use of a large inductance in the high frequency circuit.
See also *British Patent* 132799—RADIO REVIEW Abstract No. 217, March, 1920.

1581. **M. Osnos.** The Production of High-frequency Currents by Arcs and Cathode Tubes. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 487—488, June, 1920. Abstracted from *Elektrotechnik und Maschinenbau*, 37, p. 557, 1919.)

* See also *British Patent* 137564—RADIO REVIEW Abstract No. 880, October, 1920.

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1582. **J. B. Dow.** The Design of a 1 kW Arc Converter. (*Radio Amateur News*, 1, pp. 472—474, March, 1920.)
Full details and working drawings are given.

High-frequency Alternators.

1583. **O. Billieux.** Continuous Wave Transmitter. (*French Patent* 498164, November 22nd, 1917. Published December 31st, 1919.)
This specification describes a high-frequency inductor alternator which has an unwound rotor consisting of two discs oppositely rotating at equal speeds and having magnetic teeth tangentially laminated and separated and retained by non-magnetic teeth.*

1584. **M. Latour.** High Frequency Alternator. (*French Patent* 502440, September 7th, 1915. Published May 14th, 1920.)
The invention relates to a high frequency homopolar alternator in which the number of polar projections on the rotor is greater than that on the stator, in such manner that if $2m$ is the number of slots on the stator, the number of polar projections on the rotor is $(2n + 1)m$.

1585. **Ziehl-Abegg Electricitäts-Gesellschaft and M. Osnos.** Polyphase Machines of the Inductor Type. (*German Patent* 317552, October 4th, 1918. Patent granted December 24th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 501, June, 1920—Abstract.)
A polyphase machine of the inductor type particularly suitable for high frequencies in which the ratio of tooth-space to tooth-breadth is equal or nearly equal to the phase number of the machine.

1586. **Société Française pour l'Exploitation des procédés Thomson-Houston.** Continuous Wave Transmitter. (*French Patent* 505959, November 12th, 1919. Published August 11th, 1920.)
The specification describes the Alexanderson high-frequency alternator in which the inductor is provided with two circumferential rows of radial slots filled with non-magnetic material such as copper. See also *British Patent* 134830.†

Static Frequency Raisers.

1587. **J. Jonas.** Static Frequency Changers. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 481—482, June, 1920. Abstracted from *Elektrotechnik und Machinenbau*, 33, pp. 17—32, 1915.)

1588. **M. Osnos.** On the Theory and Operation of Static Frequency Doublers. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 485—486, June, 1920. Abstracted from *Elektrotechnik und Machinenbau*, 37, p. 45, 1919.)

1589. **J. Bethenod and E. Girardeau.** Frequency Multiplier. (*French Patent* 502200, filed May 28th, 1915. Dated May 6th, 1920.)
This specification describes arrangements for multiplying the frequency of an alternating current by means of static transformers. The alternator is connected to two inductances having iron cores and furnished with a continuous saturation current provided by a battery. Reactances are connected in the battery circuit to prevent the passage of the alternating current therethrough and an inductance and capacity in parallel are placed in the alternator circuit, and another inductance and capacity in parallel are connected in one of the supply wires from which the current of increased frequency is taken.

1590. **L. Moldenhauer.** Frequency Multipliers using Saturated Iron. (*Elektrotechnische Zeitschrift*, 41, p. 837, October, 1920.)
A brief reference to his Doctor-thesis on this subject.

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* See also *British Patent* 140769—RADIO REVIEW Abstract No. 780, September, 1920.
† RADIO REVIEW Abstract No. 336, May, 1920.

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Thermionic Valve Apparatus (and special Applications).

1591. **A. Hund.** A New System of Wireless Telegraphy. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 481, June, 1920. Abstracted from *Elektrotechnik und Machinenbau*, 33, p. 529, 1915.)

1592. **M. Gutton.** On Three-electrode Valves and Recent Progress in Wireless Telephony. (*Annales des Postes, Télégraphes et Téléphones*, 9, pp. 208—228, June, 1920.)
A general *résumé* of the various modes of use of a three-electrode valve followed by a consideration of its employment as a radio telephone transmitter and modulator.

1593. **A. S. Blatterman.** Regeneration and Oscillation in Vacuum Tube Circuits through Inter-electrode Tube Capacity. (*Technical Review*, 7, p. 357, December 14th, 1920.)
See RADIO REVIEW, 1, pp. 633—643, October, 1920.

1594. **M. A. Schirmann.** Calculation of Voltage Ratio of Triode with Double Grid. (*Annalen der Physik*, 62, pp. 97—106, May 28th, 1920.)
The problem is solved as a simple problem in electrostatics, *i.e.*, neglecting space charge.

1595. **W. Bragg.** Electrons. (*Electrical Review*, 88, pp. 125—127, January, 1921; pp. 156—157, February 4th, 1921. *Electrician*, 86, pp. 125—126, January 28th, 1921.)
Abstract of lecture given at the Institution of Electrical Engineers summarising our knowledge with regard to electrons and their properties.

1596. **G. Jaffé.** The Theory of High Vacuum Discharges. (*Annalen der Physik*, 63, pp. 145—174, September 28th, 1920.)
A theoretical extension of the ordinary space-charge problem to the case of an appreciable amount of residual gas and consequent presence of positive ions. The effect of a positive potential gradient at the cathode is also investigated. The results are compared with some experimental results obtained by Lilienfeld.
The paper is followed (pp. 175—178) by a communication from **Lilienfeld** in which he discusses the discrepancies between his experimental results and **Jaffé's** theory.

1597. **F. L. Hopwood.** A Demonstration of Experiments on the Thermionic Properties of Hot Filaments. (*Proceedings of the Physical Society of London*, 32, p. 244, June 15th, 1920.)

1598. **Siemens and Halske Aktien-Gesellschaft.** Valve Construction. (*French Patent* 505897, November 10th, 1919. Published August 9th, 1920.)
Two intermediate electrodes are interposed between a cathode filament and an anode. One electrode consists of a zigzag wire or net placed between two layers of wire forming the other electrode.
See also *British Patent* 134542—RADIO REVIEW Abstract No. 796, September, 1920.

1599. A Radiotelephone Operating at Six Volts. (*Everyday Engineering Magazine*, 9, p. 445, August, 1920.)
A short illustrated description of a radio telephone transmitter using an oscillating valve supplied from a buzzer-operated step-up transformer through two rectifying valves.

1600. **M. B. Sleeper.** English Radio Equipment. (*Everyday Engineering Magazine*, 9, pp. 540—541, September, 1920.)
An illustrated description of a ½ kW and a 1½ kW valve apparatus manufactured by Marconi's Wireless Telegraph Company.

1601. **F. Duroquier.** The Construction of a C.W. Transmitter and of a Radio Telephone Transmitter. (*La Nature*, 48(2), Supplement pp. 179—180, December 4th, 1920.)

1602. **J. Scott-Taggart and J. Ree.** An Ordinary Triode used as a Negative Resistance Oscillator. (*Electrical Review*, 87, p. 602, November 5th, 1920—Abstract. *Technical Review*, 8, p. 47, January 11th, 1921—Abstract.)
The authors describe the use of an ordinary pattern of triode as a negative resistance oscillator arranged on the lines of the Dynatron.

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1603. **H. H. Poole.** On the Use of Vector Methods in the Derivation of the Formulæ used in Inductance and Capacity Resonance. (*Philosophical Magazine*, 40, pp. 793—809, December, 1920.)

The equations relating to well-known methods of measuring capacity and inductances are derived directly from the vector diagrams of the bridge networks.

1604. **W. Seitz.** The Efficiency of Various Transmitting Valve Connections. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 457—460, June, 1920.)

Two different systems were tried, one with the ordinary back-coupling, and the other with an auxiliary oscillatory valve controlling the grid of the main valve. In addition to determining the efficiency in the usual way, a thermojunction was welded to the copper anode and calibrated by passing known currents through the tube without oscillations. In this way the power wasted in heating the anode was determined. With back-coupling the efficiency varied from 57 per cent. at 500 metres to 72 per cent. at 2,000 metres, whilst with the auxiliary excitation it varied from 52 per cent. at 500 metres to 78 per cent. at 1,600 metres.

1605. **W. Seitz.** On the Discontinuous Resonance Curves of Triode Oscillators. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 460—469, June, 1920. *Science Abstracts*, 23B, p. 445, Abstract No. 847, September 30th, 1920—Abstract. *Technical Review*, 7, p. 323, December 7th, 1920—Abstract.)

An experimental paper giving a number of resonance curves obtained with an ordinary triode with back coupling between the oscillatory circuit in the anode circuit and a coil in the grid circuit: a separate oscillatory circuit, representing an aerial, is coupled with the anode circuit and the curves are plotted for various values of the capacity in this latter circuit. Curves are given for a large number of cases to show the effects of the various inductances, resistances, coupling coefficients, etc.

1606. **G. Preuner and L. Pungs.** Calorimetric Determination of Efficiency of Triode Generators. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 469—479, June, 1920. *Science Abstracts*, 23B, p. 443, Abstract No. 842, September 30th, 1920—Abstract. *Technical Review*, 7, p. 290, November 30th, 1920—Abstract.)

The authors inserted the triode in a calorimeter filled with paraffin oil, which they calibrated with an electric heater. A glass vessel was used to prevent eddy current loss in the vessel itself, the glass vessel being painted black and provided with a cover of vulcanised fibre. A comparison of the energy as measured electrically and thermally with a D.C. heater showed agreement within 1 per cent. The efficiency of the triode generator was also determined by an optical method depending on the observed glow of the anode. This was adjusted to the same temperature when the circuit was not oscillating, the whole energy supply in this case being used to heat the anode. The efficiencies obtained varied from 57 to 70 per cent.

1607. **G. A. Beauvais.** Valve Construction. (*French Patent* 503641, August 4th, 1917. Published June 15th, 1920.)

To prevent the deposition of metallic films between the supports for the electrodes, screens, for example of glass, are arranged within the tube. See also *British Patent* 130040.*

1608. **G. A. Beauvais.** Valve Construction. (*French Patent* 503611, August 1st, 1917. Published June 15th, 1920.)

The grid electrode is heated by the passage of a current and the plate electrode by electronic bombardment from the grid, during the exhaustion of the tube. See also *British Patent* 130039.†

1609. **Société J. Bocuze & Cie.** Valve Construction. (*French Patent* 503206, February 22nd, 1917. Published June 5th, 1920.)

The object of the invention is to give a greater rigidity to the grid in valves, the grid being formed by a metal wire wound into a helix. One method consists in placing between the spirals of the grid a wire also wound into a helix of very small diameter and passing alternately under and over each of the grid spirals. Other methods are also described.

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* RADIO REVIEW Abstract No. 37, November, 1919.

† RADIO REVIEW Abstract No. 36, November, 1919.

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1610. **K. Rottgardt and A. Meissner.** Three-electrode Oscillation Generator. (*Elektrotechnische Zeitschrift*, 41, pp. 902—903, November 11th, 1920.)
The former writes objecting to the name "Telefunken cathode tube generator," but the latter replies that the priority of the Telefunken Company in this device is acknowledged in all countries and that it is important at the present juncture to emphasise the German origin of such inventions.

1611. **A. H. Wood.** A Laboratory Radiophone. (*Wireless Age*, 7, pp. 27—28, September, 1920.)
A description of the instrument is given with data for constructional purposes.

1612. **C. R. White.** A Small Radiophone Transmitter. (*Wireless Age*, 7, p. 27, June, 1920.)
Constructional details and dimensions are given for a small panel transmitter using two receiving valves as oscillation generators.

1613. **C. R. Leutz.** A Twenty-five Mile Radiophone Transmitter for 200 Metre Work. (*Wireless Age*, 7, pp. 15—18, April, 1920.)
Constructional details are given.

1614. **M. Latour.** Continuous Wave Generator. (*French Patent* 502601, August 16th, 1915. Published May 21st, 1920.)
The specification describes the excitation of the plate circuit of a vacuum tube generator by a source of alternating current of musical frequency, the object being to permit the reception of continuous waves with an ordinary receiving arrangement, the filament being heated by the same source of alternating current.

1615. **Compagnie Française pour l'Exploitation des Procédés Thomson-Houston.** Continuous Wave Transmitter. (*French Patent* 497446, March 22nd, 1919. Published December 5th, 1919.)
The specification describes an oscillation generating system employing a vacuum tube. For further particulars see *British Patent* 139640.*

1616. **Compagnie Française pour l'Exploitation des Procédés Thomson-Houston.** Continuous Wave Transmitter. (*French Patent* 501320, May 10th, 1919. Published April 9th, 1920.)
The specification describes a transmitting apparatus employing modulated continuous waves in which the aerial is tuned to a frequency equal to the sum or difference of the wave frequency and the modulated or amplitude pulsation frequency, and the circuit of the source of oscillations is tuned to the wave frequency, or the frequency of the source, with the object of keeping the current supplied by the source in phase with the electromotive force. See also *British Patent* 130369.†

1617. **G. A. Beauvais.** Transmitting System. (*French Patent* 503942, December 14th, 1917. Published June 21st, 1920.‡)
The specification describes a system for producing electric oscillations of the kind employing a three-electrode valve. A resistance shunted by a condenser is placed in the grid circuit of the valve and the potential at the terminals of the resistance is varied by the action of a microphone or an independent oscillating circuit.

1618. **R. F. Gowen.** A Modern Radio Telephone. (*Radio Amateur News*, 1, pp. 536—538, April, 1920.)

1619. **Captain Metz.** French Applications of the Momentous Vacuum Tube. (*Radio Amateur News*, 1, pp. 608—609, May, 1920; pp. 678—680, June, 1920.)

1620. **J. Goussin.** French Vacuum Tube Instruments. (*Radio News*, 2, p. 73, August, 1920.)

1621. **T. Brown.** Improved Vacuum Tube Circuits for Short Wave Communication. (*Radio News*, 2, pp. 212—213, October, 1920.)
In the transmitting circuit described two oscillating valves are inductively coupled to the

* RADIO REVIEW Abstract No. 883, October, 1920.
† RADIO REVIEW Abstract No. 128, January, 1920.
‡ See also *British Patent* 131018—RADIO REVIEW Abstract No. 129, January, 1920.

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aerial, and for the receiver filtering circuits are used in the anode of the detecting valve. It is claimed that stability of the beat frequency is obtained by this means when using wave lengths of the order of 150—200 metres.

1622. **J. Haas.** A Novel Radiophone. (*The Radio Amateur*, 2, p. 12, March, 1920.)

In the circuit diagrams a single valve is shown as employed both for transmission and reception without change-over switches, the receiving telephones being joined in its plate circuit and the transmitting microphone in the earth lead.

1623. **J. Scott-Taggart.** Two Laboratory Functions of the Triode Valve. (*Electrician*, 86, p. 124, January 28th, 1921.)

For the measurement of high voltages whether direct or alternating it is proposed to connect a three-electrode valve across the voltage to be measured and to increase the negative voltage applied to the grid of the valve until the plate current falls to zero. The negative voltage on the grid is taken as a measure of the voltage in the anode circuit. Any leakage in a high insulation may be detected by inserting the insulation in the grid circuit of a valve with a negative voltage in series with it and noting any change in the anode current when the insulation is connected up.

1624. **J. Scott-Taggart.** A Double Anode Vacuum Tube, A.C. Rectifier and Wireless Transmitter. (*Electrical Review*, 87, p. 298, September 3rd, 1920.)

A vacuum tube provided with two anodes is described together with its uses for rectifying by using one tube only both halfwaves of an A.C. supply. The same apparatus with the addition of a single grid electrode surrounding the filament may also be employed for wireless transmission with an A.C. supply arranged as in Fig. 1, where T is the step-up transformer, V is the special double anode valve with grid and C_1 and C_2 are two condensers to by-pass high-frequency currents round the power transformer. Almost the whole of the A.C. ripple may be eliminated by this means.

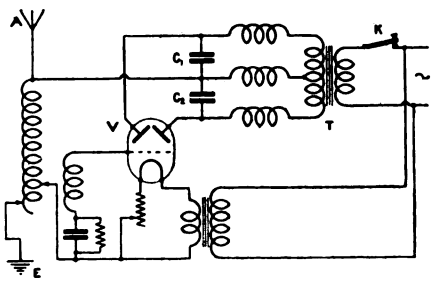

FIG. 1.

1625. **C. Loog.** Gas-filled Glow Discharge Rectifiers in the Telegraph and Telephone Service. (*Telegraphen- und Fernsprech-Technik*, 9, pp. 105—107, September; pp. 123—126, October, 1920.)

Description of bulbs containing neon, helium or argon at pressures of 3 to 10 mm by means of which the 220-volt A.C. supply can be used instead of batteries for microphone and other circuits.

1626. A Vacuum Tube with External Anode. (*Annales des Postes, Télégraphes et Téléphones*, 9, pp. 320—327, June, 1920. *La Nature*, 48(2), Supplement pp. 159—160, September 4th, 1920—Abstract.)

A *résumé* of an article published in the *Electrical World* in June, 1919, outlining experiments of three-element vacuum tubes having the anode outside the glass.* Characteristic and other curves of the tube are given.

1627. **R. Whiddington.** The Ultra-Micrometer; an Application of the Thermionic Valve to the Measurement of very small Distances. (*Philosophical Magazine*, 40, pp. 634—639, November, 1920. See also *Engineering*, 110, p. 384, September 17th, 1920; *Science Abstracts*, 23A, p. 537, Abstract No. 1350, November 30th, 1920—Abstract. *L'Elettrotecnica*, 7, p. 636, December 15th, 1920.)

In all interferometer methods of measuring small distances the accuracy of measurement is limited by the wavelength of the light used. An arrangement described in this paper is not subject to this limitation. Two oscillating valve circuits are employed one of which maintains a steady high frequency oscillation. The condenser in the oscillation circuit of the second valve is formed by two parallel metal plates, the movement of one of which is to be

* Of the type devised by **P. Donle.**

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measured. By the inter-action between the two circuits beats are produced in a loud speaking telephone connected by an amplifier to one of the oscillating valves. The constancy of the beat tone is secured by comparison with an audible frequency note set up by a third oscillating valve. It is shown that changes as small as one two-hundred-millionth of an inch can easily be detected. A simpler method of using the apparatus is described for the measurement of movements of the order of a one-hundred-thousandth of an inch.

1628. **J. A. Eyster.** An Audio-frequency Vacuum Tube Generator. (*Journal of the American Institute of Electrical Engineers*, 39, pp. 888—889, October, 1920. *Science Abstracts*, 23B, pp. 569—570, Abstract No. 1085, December 30th, 1920—Abstract.)

The author describes the development of a vacuum tube alternating current generator particularly for use in A.C. bridge measurements where a pure sine wave current is required. The complete apparatus is illustrated and constructional details are given.

1629. **R. T. Beatty and A. Gilmour.** On the Measurement of Changes in Resistance by a Valve Method. (*Philosophical Magazine*, 40, pp. 291—295, September, 1920.)

The resistance to be measured is included in the grid circuit of an oscillating valve and is shunted by a small condenser. Curves are given connecting the resistance in ohms with the frequency of the oscillations for different values of the capacity. Measurements are made by observation of the silence points which occur for particular adjustments of the resistance. The method may also be applied to the comparison of the capacities of condensers from a few centimetres to about 1μF.

1630. **H. Abraham, E. Bloch and L. Bloch.** Direct Reading Apparatus for the Measurement of Alternating Currents; the Amplifying Voltmeter. (*Journal de Physique et la Radium*, 1, pp. 44—57, August, 1920.) Also **H. Abraham.** (*Annales des Postes, Télégraphes et Téléphones*, 9, pp. 197—207, June, 1920. *Bulletin de la Société Belge des Électriciens*, 34, pp. 245—246, October, 1920—Abstract.)

After a brief introduction on the triode tube and its use as an oscillation generator, detector and amplifier the author's amplifying voltmeter is described following the general lines of a previous paper.* Some of the applications of the apparatus are briefly referred to.

Transmitter Control or Modulation.

1631. **L. F. Fuller.** New Arc Method for Continuous Waves. (*Wireless Age*, 8, p. 19, November, 1920. *Science Abstracts*, 23B, p. 582, Abstract No. 1114, December 30th, 1920—Abstract.)

The article outlines the signalling method described in *British Patent* 131561.†

1632. **P. J. Lault.** Continuous Wave Transmitter. (*French Patent* 505328, October 23rd, 1919. Published July 28th, 1920.)

The system described is an arc generator system with the sending key inserted in the antenna circuit. An auxiliary circuit having a short wavelength is connected across the arc to prevent its extinction when the antenna circuit is interrupted. The capacity in the shunt circuit is made approximately the same as the antenna capacity.

There is a corresponding *British Application* No. 152970, the patent on which has not yet been granted.

Books Received.

LONGUEURS D'ONDE ET PROPAGATION. By M. Vieillard. (Paris: *Gauthier-Villars et Cie.* 1921. 10 × 6½ ins. Pp. xii + 416. Price not stated.)

JOURNAL AND RECORD OF TRANSACTIONS OF THE JUNIOR INSTITUTION OF ENGINEERS. Edited by W. A. Tookey. (London: *Percival Marshall & Co.* Vol. 30. 1920. 8 × 5½ ins. Pp. vi + 408 + cx. Price 15*s.*)

WIRELESS TELEGRAPHY: WITH SPECIAL REFERENCE TO THE QUENCHED SPARK SYSTEM. By B. Leggett, A.M.I.E.E. (London: *Chapman and Hall, Ltd.* 1921. 8½ × 5½ ins. Pp. xv + 485. Price 30*s.* net.)

* RADIO REVIEW Abstract No. 1415, January, 1921.
† See RADIO REVIEW Abstract No. 189, February, 1920.

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Correspondence.

INDUCTANCE CALCULATIONS.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—From time to time formulæ and tables have been published in the RADIO REVIEW with a view to facilitating the calculating of inductances of air-coil solenoids.

In this connection, details of a special calculator of slide rule form which I devised some years ago may be of interest.

The calculator is constructed on the basis of Professor Nagaoka's well-known formula for single-layer coils, namely :—

$$L = \pi^2 d^2 n^2 l k$$

where d = diameter in cms

n = turns/cm

l = length in cms

and k is a function of l/d

The formula may be re-written :—

$$L = d^3 n^2 \left(\pi^2 \frac{l}{d} \cdot k\right)$$

$$= d^3 n^2 P$$

where P is also a function of l/d.

The calculator is therefore constructed with scales corresponding to :—

log L

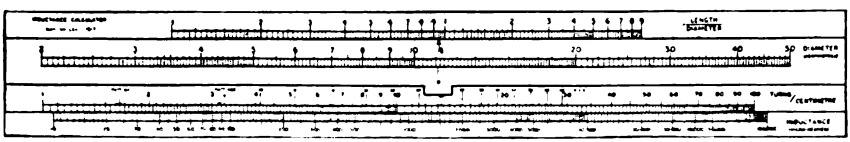
log d^3

log n^2

log P where $P = f(l/d)$.

The last scale while being spaced out according to log P is engraved in terms of l/d.

Referring to the photograph it will be seen that the actual rule is arranged with the P scale



at the top and that the limits within which the rule will operate are respectively :—

l/d	0·1 to 9
Diameter	2 to 50 cms
Turn/cm	1 to 100
Inductance	10 to 100,000 microhenries

which are sufficient for most purposes.

The scale of "turns per centimetre" has marks on it corresponding to the various gauges and coverings of wire, which is found to be a very useful arrangement, but these markings must be used with caution owing to possible variations in space factor with the method of winding.

An accuracy of 1 to 2 per cent. in the calculated inductance value is usually obtained and

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the errors arising when the calculator is used for multi-layer coils are small enough to be neglected, at any rate as a first approximation.

Radio Communication Co., Ltd., NORMAN LEA.
London, *January 25th*, 1921.

MICA CONDENSERS FOR RADIO WORK.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—We have noted in the December, 1920, issue of the RADIO REVIEW, the article entitled "Mica Condensers for Radio Work," on page 768. In reading this article one is led to believe that the Wireless Specialty Apparatus Company is no longer in the mica condenser business, and has been an infringer, rather than an important contributor in the development of the mica condenser. The Wireless Specialty Apparatus Company are now, and have been, very actively engaged in this business and its development, and have established an enviable reputation as the designers and manufacturers of the Faradon condensers. We are giving here a short review of the suit brought against the Wireless Specialty Apparatus Company by the Dubilier Condenser Company, and of the important part we have played in the development of mica condensers.

The following facts concerning mica condensers will be of interest to your readers supplementing those stated in your article of December, 1920. The first article was incomplete in that it did not include mention of the facts involving the Wireless Specialty Apparatus Company in the situation in such way as to bring out the fact that it is now the only company having the right to manufacture the efficient modern form of high voltage mica condenser, as hereinafter described, and our thought is that you will be glad to avail yourself of the additional facts submitted below which will correct any false impression which the first article might convey contrary to the facts.

It might appear to the uninitiated that it would have been impossible during recent years to improve materially on the series sectional mica condensers for high potential and radio service which previously had been used for a considerable period, especially in the United States Navy Radio Service. While it is quite true that those earlier condensers had employed a series sectional feature, yet in view of the much greater success attendant upon the introduction in more recent years of the modern form of the series sectional type, it is not surprising to learn the fact that this condenser embodies in part ideas disclosed in the Dubilier patents and applications which are of very vital novelty and in part ideas originating with the Messrs. Pickard and Priess of the Wireless Specialty Apparatus Company, and other employees of the company, and embodied in the present form of highly efficient mica condenser as now manufactured by our company for transmitting, receiving, and power factor work, each feature working together with the feature of sectionalising to the result of a high efficiency and small volume.

The ideas shown in more or less undeveloped form in the Dubilier patents were developed by the Wireless Specialty Apparatus Company, at the request of the United States during the war emergency, in combination with its own inventions, with the result of producing what the trade now recognises as the modern type of mica condenser, known as the Faradon.

The features originated by Wireless Specialty Apparatus Company include matters of construction and of processes of manufacture substantially as follows.

At the outset of its condenser work, the Wireless Specialty Apparatus Company developed accurate methods of measuring the comparatively low losses found in mica condensers, employing these methods the company's engineers were enabled to logically investigate the causes of and reduce to a minimum such losses as—

(*a*) Dielectric losses due to the quality of mica.
(*b*) Composite dielectric of the mica and the filler.
(*c*) Filler losses due to the dielectric hysteresis of the particular fillers in use and the homogeneity of the filler.
(*d*) Brush losses due to non-homogeneity of the filler, imperfect contact between conducting elements in the condenser and the mica.
(*e*) Value of dielectric strain per unit thickness of mica in a section.
(*f*) The ohmic loss in condenser conductors.

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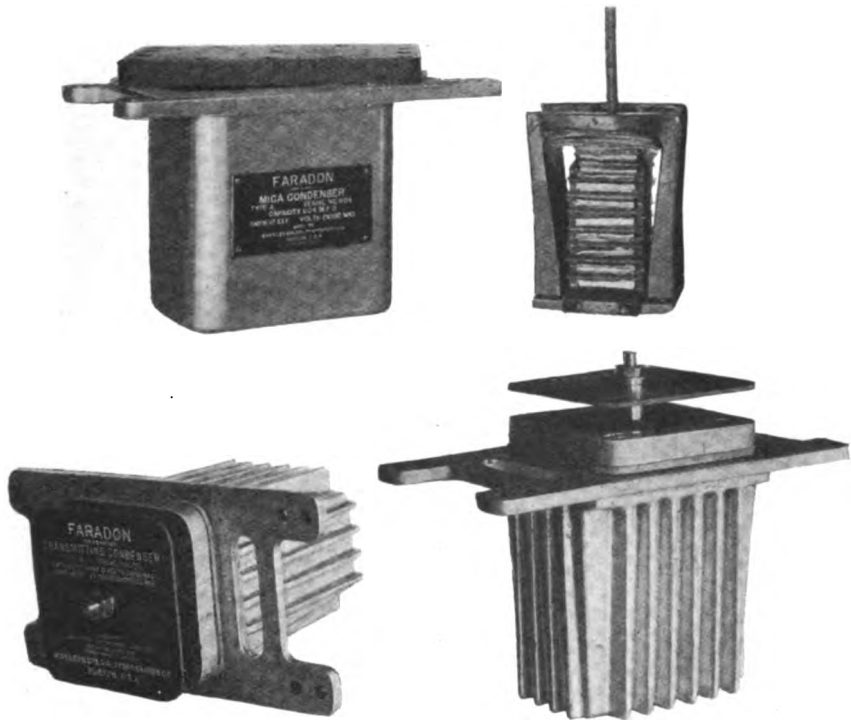
(*g*) Effective leakage resistance of the condenser.
(*b*) Poor thermal conductivity between the condenser stack and the radiating members.

The company then proceeded to develop practicable embodiments to maintain in the completed condenser the high degree of efficiency developed in their condenser research.

Several very important methods were developed which co-operated to select the quality of mica necessary for producing the condenser of the high order of efficiency of the United States Naval Laboratories. Manufacturing processes were developed to produce substantially perfect contact between the conducting and mica elements in the condensers. A filler was developed of low dielectric loss, high dielectric strength, and a high thermal conductivity, chemically stable under conditions of high dielectric stress, and wide changes in temperature. The best form and material for the conducting elements, the correct sectional voltage for different thicknesses of mica, and the best sheet margins were determined.



Types of "Faradon" Condensers, showing the Method of Construction.

Manufacturing methods were developed for embedding the condenser within the casing in a holosteric filler, *i.e.*, a filler free from voids, and homogeneous. The leakage resistance from the high potential terminal to the casing within the casing was made practically infinite by obtaining intimate contact between the filler and the casing at the high potential end of the condenser. A manufacturing method was developed for obtaining intimate contact between the conducting elements and the mica sheets, excluding composite insulation to the highest practicable degree.

Designs were developed for taking care of the loss developed in the condenser by providing a very good thermal path between the stack and the casing. The casing was designed with a maximum radiation surface for transferring this heat to the surrounding air. A radiating

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member was added to the high potential terminal to assist in reducing the temperature of the sections of the condenser nearest the high potential terminal. In some designs, maximum thermal conductivity from the stack to the casing, *via* the stack axis, was obtained by placing two or more series section stacks electrically in parallel in the casing and having one surface of each of the stacks in contact with the casing and connected to it. This design produced a condenser of low cost due to the use of comparatively small area sheets of mica and having the thermal conductivity of a condenser of much higher cost, based on the use of mica sheets of area equivalent to the sum of the areas of sheets in contact with the casing. The spacing between the condenser stack and the casing was determined so that the dielectric strength of any portion of the path between stack and casing possessed a voltage safety factor equal to that of the stack, thereby producing a condenser having a minimum of filler and therefore a maximum of thermal conductivity between the stack and the casing *via* the filler.

Many designs were evolved. The pressure on the stack sufficient to maintain the intimate contact produced in the process of manufacture was retained in the final condenser, by novel clamping means developed by the company's engineers. For some classes of service, the clamping means was made elastic, vanadium steel in general being used as the spring members. These springs retain pressures of the orders of a ton per square inch of the active area on the condenser stack and maintain this pressure over wide variations of temperature of the condenser unit. Through the above-mentioned designs and the result of careful research over several years, the Faradon condenser has been evolved. This condenser had a phase angle at 20° C. of approximately one minute and twenty seconds. The best condensers that we have tested previous to our designs measured in the neighbourhood of four minutes.

The above and other features originated by Wireless Specialty Apparatus Company are the subject of patent protection by a large number of applications for patents, and the company has not authorised any one to use them. Furthermore, as the result of the recent litigation in the United States courts under two Dubilier patents and involving the manufacture for and sales of condensers to the Government during the war by Wireless Specialty Apparatus Company, the latter company acquired exclusive commercial rights with the plaintiff, under the two Dubilier patents in suit and seven other Dubilier patents not involved in the suit, in addition to four Dubilier applications for patent. The Dubilier Company, however, did not receive any patent rights or licences from Wireless Specialty Apparatus Company. Furthermore, no one else has been authorised by the Wireless Specialty Apparatus Company to make, use or sell any of the inventions of any of its various patent applications, either with or without the inventions of the Dubilier patents, that is to make, use or sell the modern form of sectional mica condenser for high voltage use as known to the trade during the last few years.

I might add that the United States also received a licence to use the inventions of the Dubilier patents and applications as a result of the court's decree, although the United States did not receive any licences under the inventions of our company.

Inasmuch as you showed several photographs of Dubilier's condensers, it will be, no doubt, of interest to your readers to see the constructions of two of our standard types, photographs of which are enclosed for publication.

Very truly yours,
W. J. HENRY,
Production and Sales Manager.

Wireless Specialty Apparatus Company,
Boston, Mass., U.S.A.,
January 15th, 1921.

ERRATUM.

Page 76 (issue for February, 1921), *Fig.* 1. *The following caption should be added below the figure :—*

EFFECT OF AN IMPURITY ON THE IONISATION POTENTIAL OF HELIUM.

The curves A to E were taken at the following times after commencement of the tests :— A = 0 minutes ; B = 30 minutes ; C = 430 minutes ; D = 550 minutes ; E = 730 minutes.

Fig. 2. *This diagram should be marked :—*Aged 190 minutes.

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THE RADIO REVIEW

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PROFESSOR G. W. O. HOWE, D.Sc., M.I.E.E.
Assistant Editor:
PHILIP R. COURSEY, B.Sc., A.M.I.E.E.

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THE

RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

Editor: Prof. G. W. O. HOWE, D.Sc., M.I.E.E. Asst. Editor: PHILIP R. COURSEY, B.Sc., A.M.I.E.E.

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THE RADIO REVIEW

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THE
RADIO REVIEW

VOL. II APRIL, 1921 NO. 4

Editorial.

Range of Wireless Stations.—The current number of the *Journal of the Institution of Electrical Engineers* contains the paper with this title recently read by Captain Trench together with the discussion thereon. A perusal of the discussion impresses one with the lack of data upon which to base any calculation of the power required to cover a given distance. The most important and fundamental figure which one requires to know is the strength of the electric field required at the receiving station in order to guarantee easily-readable signals twenty-four hours per day and seven days per week, local thunderstorms excepted. This will depend to some extent on the frequency employed, on the geographical position of the station, on the efficacy of any devices employed for the elimination of atmospheric disturbance, on the speed of working and on other factors. Attention was drawn to the fact that Captain Trench based his calculations upon a power in the receiving antenna only a fifth of that assumed in our article in the September number of the RADIO REVIEW. This discrepancy is a confession of our ignorance of the actual field strength required in any given case to ensure continuous reception with the best modern apparatus. It would be of great service if data could be collected of actual stations of modern design in all parts of the world which can just receive continuously or for say 90 per cent. of the time from other stations of known characteristics.

It is well known that all the early estimates of the power required to cover a given distance have been falsified. Experience has shown that far greater powers are necessary to ensure a reliable service.

In his reply to the discussion Captain Trench says that he leaves it to the verdict of general experience to say whether 2 kW in the aerial would not give easy communication over 4,000 km with modern valve reception and amplification.

We fear that the verdict has already been given by all those engineers who have been responsible for long-distance radio stations. It is a verdict based upon bitter experience and is exemplified in such things as 1,000-kW arcs and discussions as to the possibility of the parallel running of 500-kW radio frequency alternators.

Some Thermionic Tube Circuits for Relaying and Measuring.—A paper with this title by Dr. W. H. Eccles and Miss W. A. Leyshon was read before the Wireless Section of the Institution of Electrical Engineers on March 16th. The underlying idea embodied in the paper was the use of a

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saturated diode as the load in the plate circuit of a triode. To obtain a large voltage amplification it is necessary that the load in the anode circuit should have a high resistance to oscillations, whereas its resistance to continuous currents should be as small as possible in order to avoid the necessity of a high E.M.F. in the anode battery. Expressed mathematically $\frac{dV}{dI}$ should be big and V/I small. An inductance has this property, but in a degree depending on the frequency; a saturated diode maintains the same current ($dI = 0$) for all variations of dV over a certain range, and dV/dI is therefore infinitely great. The use of a diode in this way has been suggested by several physicists. The authors of the paper used it in order to determine the voltage ratio of the tube $\partial V_p/\partial V_g$ when the plate current I_p is kept constant. The saturated diode in the plate circuit relieves one of any trouble in maintaining this latter condition. It should be pointed out, however, that the geometrical conception of the voltage ratio implies that the total emission current is kept constant; as soon as the grid is made sufficiently positive to take an appreciable current, a new factor is introduced which has no connection with the geometrical conception of the voltage ratio. This was clearly shown in the curves given in the paper, the voltage ratio being constant under all conditions only so long as the grid current was zero.

The Effect of Emission on Filament Temperature.—A short but interesting paper on this subject by Mr. G. Stead was read before the Wireless Section of the Institution of Electrical Engineers on March 16th. The experimental work was done three years ago for the Admiralty. Pyrometrical observations were made at various points along the filament with various values of emission current, keeping the filament current *as read on an ammeter in the positive filament lead* constant. The resulting temperature changes which are plotted in the paper are due to two causes, viz., (1) the cooling due to the energy carried off by the emitted electrons and (2) the variation of current along the filament due to the emission. The paper serves to emphasise several points which are always a source of uncertainty in connection with thermionic devices. The characteristic curves are very dependent upon the filament temperature and it is therefore important to specify it as accurately as possible. If an ammeter is inserted and its reading kept constant, different results will be obtained according to whether it is connected in the positive or negative lead since the emission current divides between the two limbs, increasing the current in one and diminishing it in the other. By inserting three ammeters, one in each limb and one in the anode circuit, one can calculate the true filament current and the two parts of the emission current and can keep the former constant if this is required.

Some experimenters have tried to keep the filament temperature constant, but here again one is in difficulties since the distribution of temperature along the filament depends on the emission current.

Another matter of interest is the difference which must exist between the static and dynamic characteristics since when the emission current is

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varying with a high frequency the filament temperature will not follow the rapid fluctuations but will assume a mean value at each point. Deductions based on the static characteristics must therefore be modified when applied to high-frequency oscillations.

To the Authors of Scientific Papers.—The editors of seventy German scientific journals have issued a joint notice to all their contributors with the object of increasing the general efficiency of such publications. The notice appears in the February issue of the *Jahrbuch Zeitschrift für drahtlose Telegraphie*. It embodies eight paragraphs and is commendably brief and to the point. We give here a translation and commend it to all our contributors:

(1) Before starting scientific work find out exactly what has already been published on the subject.

(2) Every article should be carefully planned and the sub-divisions made clear. The manuscript should be ready for the printer, preferably typewritten on one side of the paper; bad handwriting and subsequent alterations add considerably to the cost.

(3) Keep the article within the narrowest limits, avoid foreign words and choose the most careful German; omit lengthy introductions, developments, and unnecessary calculations.

(4) As far as possible replace lengthy descriptions by diagrams. Insert all scales and figures in drawing-office style. Brief particulars under the diagrams increase their value and replace long descriptions.

(5) Diagrams should only contain the essentials; omit secondary details or well-known matter. If already published elsewhere give references.

(6) Carefully observe editorial suggestions for shortening the article. Generally speaking, the shorter the article the greater its effect.

(7) Before sending in criticisms for the correspondence columns try to come to some agreement with the author.

(8) Never offer an article to a second journal until the first one has declined it. Any second publication should contain only short abstracts from the main publication.

The Lafayette Radio Station.—As a result of the preliminary tests and working of this new high-power station referred to in our February issue (pp. 85—93) it appears from a report published in *Radioélectricité*, that while its power is ample for communication with the United States, it is still insufficient for continuous traffic with South America or with the East—*i.e.* over ranges of 10,000 kms or more. The signals at these distances are seriously interfered with by atmospherics. For example at Hanoi the signals from Croix d'Hins can be heard strongly between 2100 and 0500 G.M.T., but at other times they fade. Similarly at Shanghai the signals are unreadable between 1700 and 1900, although they are strong at 2100 G.M.T., and throughout the morning. This is apparently one of the reasons underlying the project for the large Paris Radio Centre upon which work has now been commenced. Further details of this project were published in our March issue. [2120]

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Some Recent Designs for Ship Radio Installations.*

By H. R. RIVERS-MOORE, B.Sc., A.M.I.E.E.

Some standard equipments suitable for ship or other stations, which possess several features of interest, have recently been developed by Messrs. R. M. Radio, Ltd. The larger sets, of 1½ and ½ kW respectively, are similar in general conception, and a description of the latter will sufficiently indicate the main features of both. The set is of the rotary spark type with the familiar inductively coupled arrangement of circuits (see Fig. 1) and the design aims particularly at the achievement of simplicity and accessibility with small bulk, with a view to providing an equipment which can easily be fitted and maintained in vessels having limited space, and which offers little complication to the operator in charge.

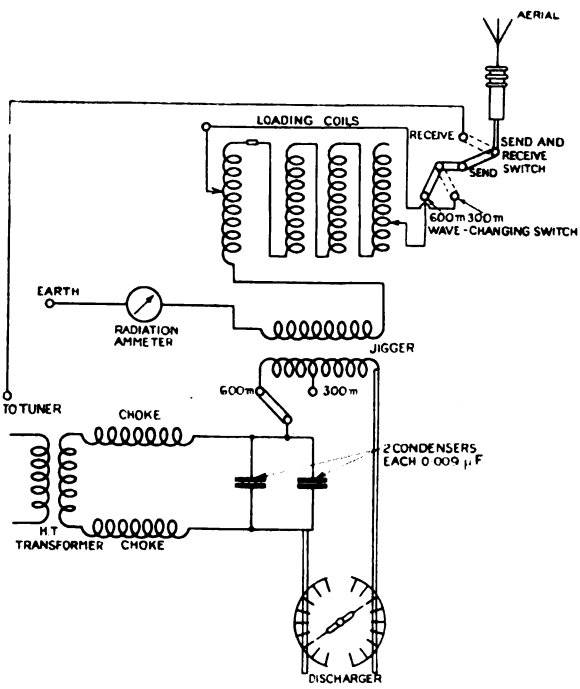

FIG. 1.—High Tension Wiring Diagram of ½ kW Set.

Transmitter and receiver are fitted in a single cabinet (Fig. 2) which also embodies the operating table. This cabinet is only 3 feet wide and both sides are kept clear of projections or controls so that this represents the total width of space needed to accommodate the set.

Advantage is taken of the absence of any physical connection between the primary and secondary oscillating circuits, to build up the former entirely on the motor alternator (see Fig. 3) which slides on runners into and out of the space in the lower part of the back of the cabinet. The runners are continued on the inside of the falling door which encloses the primary transmitting unit, and thus, on opening this door, the whole unit can be drawn forward into an accessible position. The leads to motor and alternator are

* Received March 16th, 1921.

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of strong workshop flexible and are connected to terminal strips inside the cabinet. They are of sufficient length to allow of the machine being drawn out and run in the exposed position if required.

To the generator carcase, at the alternator end, is fixed the cast aluminium discharger housing, which has a flat top on a level with the top of the machine Covering the whole is a teak platform on which the primary high tension

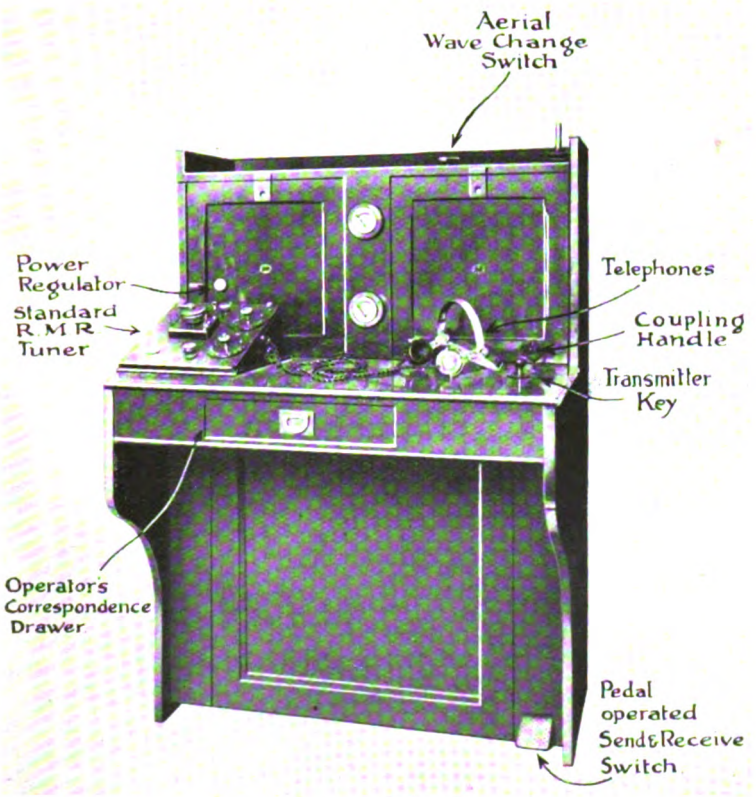

Fig. 2.—½ kW Spark Set.

unit is built up. At one end is the high tension transformer and about the middle a bank of Dubilier condensers and a pair of air-core protecting chokes constructed to be of the same size as one of the condensers. The condensers and chokes are all contained in a teak outer case from which they can readily be removed by sliding them out. The transformer is mounted on a small hinged piece so that it can be tilted out of the way and the high tension leads from the transformer, which are only about 2 inches long, terminate

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in plugs which engage in sockets in the choke coils. Thus the replacement of a condenser is only a matter of seconds.

The arrangement of the connections of the primary oscillating circuit adds to the ease of changing condensers and also avoids the use of flexible connections, while keeping the area enclosed by the circuit a minimum. It will be seen from Figs. 3 and 4 that the air core chokes and the condensers are provided with heavy copper clips in lieu of terminals and that these

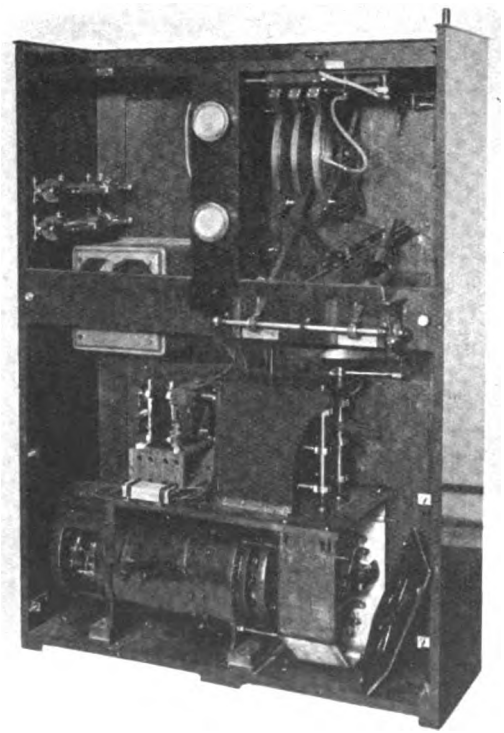

FIG. 3.—Interior of Set.

clips engage with tubular copper connectors running vertically. The tube on the left in Fig. 3 interconnects one choke and one side of each condenser and is extended by means of a copper rod into the discharger housing below, where it connects to one side of the discharger. From the other side of the discharger a rod runs concentrically up through the right-hand tube, and insulated from it throughout by an ebonite tube, and is screwed into a boss which forms the centre and starting point of the pancake winding of the jigger primary, of heavy copper strip. This rod in fact supports the jigger

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primary which however is also upheld and steadied by ebonite pillars at the extremity of two of the cross arms. At proper points on the jigger primary to give the required wavelengths special contact clips are attached which can be seen projecting downwards. They can be adjusted to any required position. The right-hand tube already mentioned carries a contact arm or blade corresponding to each of the wavelength clips, and as these blades are gripped by friction clamps on to the tube, they can be set into positions corresponding to those of the jigger clips with which they have to engage, in such a way that a fixed angular movement of the tube will cause engagement of a particular blade with its corresponding clip, wherever the latter may have been placed. Thus a wave-change switch is provided which has the advantage that it involves neither flexible leads nor pivot contacts. Where however more than three waves are required it becomes difficult to keep the blades and clips sufficiently separated for insulation purposes and a modified form is used involving short flexible leads and fixed contact clips.

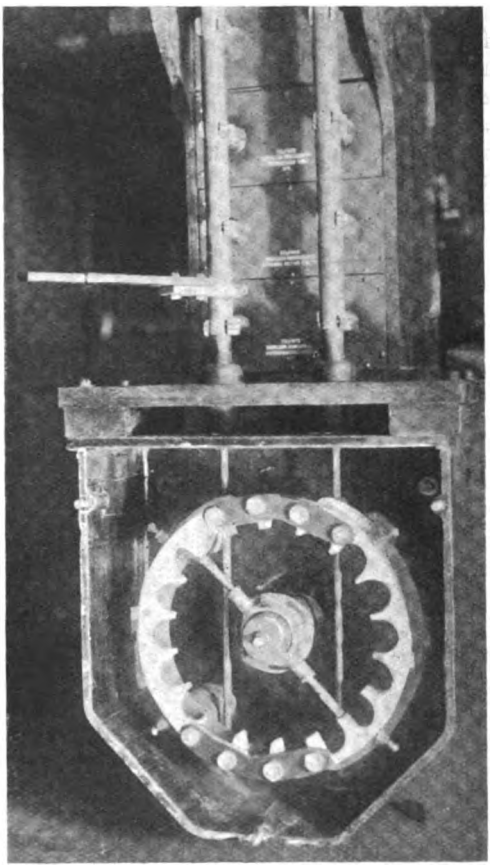

Fig. 4.—Rotary Spark Gap and Condensers.

The discharger is somewhat unusual inasmuch as it consists of a crown of fixed electrodes and only two rotating electrodes. The arrangement is illustrated in Fig. 4. The crown is originally cast and machined as a single piece to ensure accuracy and it is then divided into two portions and reassembled with insulating clamps without upsetting the alignment. The whole crown is then fitted adjustably into brackets which are in electrical connection with the copper rods mentioned above. The crown is held by four pointed screws which fit into a V-groove running all round its outer surface and by their means it can be adjusted centrally with respect to the shaft of the motor-alternator which carries the two rotating electrodes. Leaving the four screws slightly loose in the groove the phase relation can readily be adjusted by rotation of the crown, after which all the screws are tightened up.

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The more usual arrangement in which the whole housing carrying two fixed electrodes is swung for phase adjustment, does not lend itself to the rigid platform construction adopted for the primary unit. Apart from this consideration the fact that the two electrodes which have the heaviest work are in rapid rotation causes most efficient cooling and it is found quite unnecessary to provide a large mass of metal or any special cooling vanes for them. They are themselves of flat form and act as fans. The power needed to drive these electrodes should be less than in the case of a multiple rotating electrode. The spark obtained is of excellent quality and very penetrating. The spark frequency is 700 per second.

The spark occurs, of course, at different points round the circle in succession and the appearance produced is quite spectacular, as there is a crown of brilliant sparks and the rotating electrodes appear stationary and multiplied like spokes of a wheel. Any fear of the inductance of the circuit being varied owing to the spark occurring in different positions is overcome by the arrangement by which each half of the crown is connected electrically to its bracket at three points, namely the two at which it is held by the screws and an additional flexible lead of woven copper at the mid point, introduced as a safeguard.

Earthed condensers mounted on the platform of the unit serve to protect the windings of the machines.

Immediately over the jigger primary when the unit just described is in position in the cabinet (see Fig. 2) is the secondary, consisting of another pancake winding of copper strip, mounted on a frame pivoted along one edge and controlled by a handle conveniently situated for varying the coupling.

The remainder of the space in the right side of the upper part of the cabinet is occupied by the loading coils, of pancake form, and the secondary wave-change switch. In later forms it is proposed that a single handle shall control both primary and secondary wave-change switches. The loading coils are banked together with plug and socket connections so that only the actual number necessary with a given aerial need be fitted.

The send and receive switching arrangements call for comment. The aerial is connected to the apparatus by means of a plug which fits into a socket in a small leading-in insulator in the top of the cabinet. This socket is formed in the upper end of a brass rod which is actually the pivot of the send and receive switch and carries the switch blade at its lower, inside, end. Thus no current has to pass through any moving contact but as the switch blade turns from "send" to "receive" position the aerial plug makes a small angular movement which is easily absorbed by the flexible lead from the deck insulator.

The movement of the "send and receive" switch blade is controlled by a pedal beneath the desk and the same pedal gear operates a small switch which controls the automatic starter for the motor generator. Thus the entire switching operation is completed in about three seconds by merely depressing the foot. On removing the foot a spring pulls the aerial switch into the "receive" position and the automatic starter switch falls back into the "off" position. The switch pedal is quite light and no fatigue is

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involved in keeping it depressed and the whole arrangement is remarkably convenient and simple, leaving the operator's hands entirely free. An alternative hand control is provided and can readily be changed for the other if preferred.

Save only the automatic starter all switches are directly controlled by straightforward levers which are fully exposed by opening the cabinet. The operator has everything under observation and there is nothing intricate to get out of order.

Behind the left side panel of the upper cabinet are two sliding rheostats

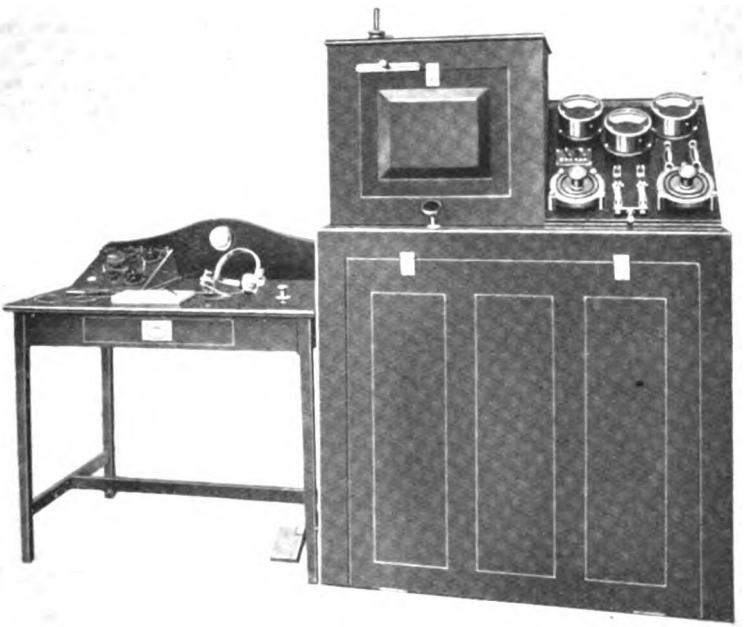

Fig. 5.—1½ kW Spark Set showing Cabinet and Operating Table.

controlling the speed and power of the generator by means of handles projecting through the panel. No other adjustments are provided in this set. There are two ammeters in the slip dividing the two removable panels of the upper cabinet, one of which indicates the key current and serves as an indication of power taken; the other gives the aerial current and is used for tuning and as an indication of power output. A low frequency choke is provided, of fixed value determined before the set is issued. The operator therefore has only to vary his power according to requirements and then vary speed until the best note and aerial current are obtained. The discharger once set should not be altered except as the electrodes burn away.

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It will be seen that the object has been to provide minimum opportunity for throwing the set out of gear and to simplify the adjustments to those required by the authorities, namely wave change, coupling and power variation, with in addition a small speed variation for securing low frequency resonance and a good note.

The key is of the simplest and most usual description but is inverted and mounted beneath the desk with the knob only projecting above. Adjustments of travel and tension can be made by putting the hand beneath the desk and the key is connected by plug and socket and can be withdrawn readily for replacing contacts.

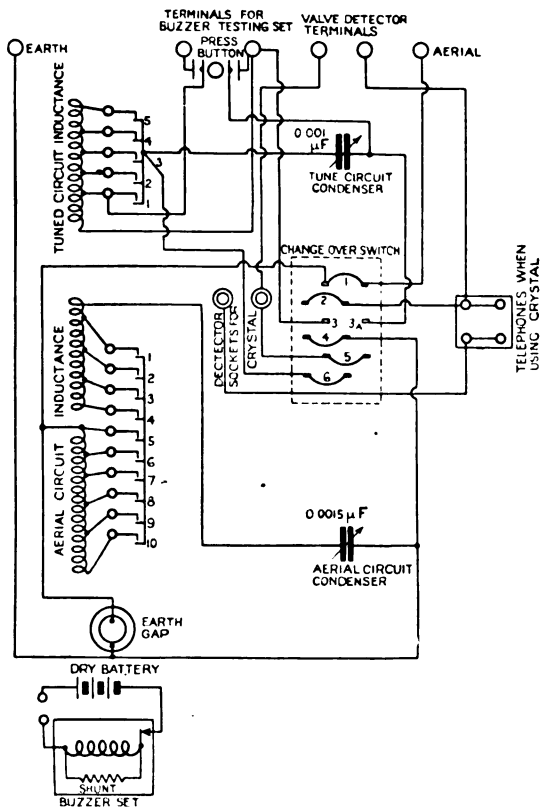

FIG. 6.—Wiring Diagram of Receiver.

The transmitter for the 1½ kW set (Fig. 5) differs in that the lower portion of the cabinet is a silence chamber with cork filled walls. A variable low frequency choke is provided, and a slate switchboard with instruments for measuring D.C. and A.C. volts and amperes. While retaining the main features and simplicity of the smaller set it provides rather more adjustments and facilities which can be utilised by an operator who wishes to get the best out of his instrument. The receiver and signalling key are fitted on a bench or table separated from the transmitting plant.

The standard form of receiver is the same for both ½ and 1½ kW sets. In the former case it is fitted into a recess in the operating desk, with the upper face, containing the adjusting handles, set at a slope for easy handling. The tuner provides aerial tuning inductance and condenser and there is a closed circuit similarly variable and coupled adjustably to the aerial circuit by a coil swinging on its own axis (see Fig. 6). The wavelength range is from 250 to 3,500 metres.

Provision is made for detection either by valve or crystal, the valve being fitted in the left side panel of the cabinet when required. This is not shown in the illustration and it is proposed in future to incorporate it in the tuner.

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The tuner can easily be lifted from its recess and used as a wavemeter. Two terminals and a press-button are provided, connected to some turns of the closed-circuit inductance. A small separate case containing a buzzer and dry-cells is provided with contact pieces to engage these terminals and thus provide means for testing the crystal setting and also for using the tuner as a transmitter wavemeter. For testing the crystal the change-over switch should be placed in the " stand-by " position and the closed circuit brought into resonance with the aerial circuit. In order to avoid absorption of energy by the closed circuit when listening on the " stand-by " adjustment with the closed circuit coupled and set to the same wavelength, the change-over switch opens the " tuned " circuit when in the " stand-by " position. It is therefore necessary to provide an additional contact on the buzzer key to close the circuit automatically when the buzzer is used.

The object in having the buzzer and its battery in a separate box is merely for accessibility in changing the battery or adjusting the buzzer.

The tuner is provided with a safety earth gap of brass plates separated by a mica disc, the sparking surface being totally enclosed to keep out dust.

A valve of special form is used which we hope to describe fully in another article, but standard " R " valves can be used.

The crystal detector consists of a revolver drum, of ebonite, carrying eight small cartridges. The cartridges comprise a cylindrical body of ebonite within which are two very small crystal cups pressed together by a spring which is adjustable from the outside at one end by a small screw-driver. By turning the drum a fresh cartridge is brought into action and connected between a brass anvil below and spring contact above the drum, so that it is the work of a moment to change from a crystal which has become insensitive. Eight cartridges are carried in the drum and a further supply can be kept ready adjusted to replace these when required. The first set can then be re-adjusted at leisure in readiness for further use. If trouble is experienced from the transmitter rendering crystals insensitive, a " half-cock " position of the drum disconnects the cartridge completely and leaves only the very small brass mountings of the cartridge in contact with the crystals to pick up oscillations.

We hope in a later article to give a description of the several forms of ¼ kW and emergency equipments manufactured by the same firm.

Measurements of Radiation of Radiotelegraphic Aerials.

By G. VALLAURI.

(*Concluded from page* 143.)

12. Experimental Results.—The first attempts at systematic measurements of radiation and the first applications of same to the rational study of the shape and properties of aerials, were probably made by the Royal Italian Navy. After a first phase of study and research work, standard measure-

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ments of radiation were made on September 13th and 19th, 1916, on the aerial of the Taranto Wireless Station (Fig. 7). In these measurements only half the aerial was used, consisting of three wires ($\lambda_0 = 1,500$ m; $C = 3{\cdot}62$ mμF), and it was excited by a 3 kW Poulsen arc generating a current of about 10 A with various values of λ between 2,500 and 4,500. The receiving aerial, placed on the Island of S. Pietro ($d = 12{\cdot}1$ km) was a closed vertical frame of rectangular form with an area $S_r = 680$ m^2. The induced currents were of the order of some tenths of milliamperes, they were measured by a thermoelectric couple in vacuo, connected with a reflecting galvanometer. The resistance of the receiving circuit was measured by the insertion of a known resistance both with impulse excitation produced by a buzzer, as well as by the excitation due to the wave transmission to be measured. The effective height in the direction considered, which formed an angle of 61° with that of maximum radiation (according to the known properties of bent antennæ), was found to be 56·5 metres.

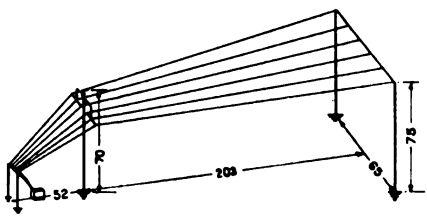

FIG. 7.

More exact measurements were carried out in 1917 for the Rome Wireless Station (San Paolo), by installing the receiving station on the beach of Fiumicino ($d = 23{\cdot}2$ km) with a closed rectangular aerial the area of which was 531 m^2, far from any disturbing local influence. The instruments were placed in a small shed. As receiver, a Duddell thermogalvanometer with a 4 ohm heater was used.

The calibration was carried out by inserting the Duddell galvanometer in a local circuit containing a resistance box and an accumulator, the voltage of which was measured at the same time by a precision voltmeter. From the readings δ_1 for different values of the resistance R of the box, and the zero reading δ_0 one gets the deflection $\Delta = \delta_1 - \delta_0$; and from the ratio between the value of the current $I = \dfrac{V}{R + 4}$ and $\sqrt{\Delta}$ we get the constant of the thermogalvanometer $K = I/\sqrt{\Delta}$. For the measurement of the received current and of the resistance of the receiving oscillatory circuit, it had been agreed that the transmitting station (Poulsen arc) at determined hours should alternate constant emissions lasting ten minutes (each with a given wavelength), with pauses also of ten minutes duration. During every transmission, the opening minutes were devoted to carrying out the accurate tuning of the receiving circuit, the capacity being varied until the maximum deflection had been obtained at the galvanometer. After this the measurement was begun, following a regular programme of readings; viz.: δ_0 (open circuit zero reading), δ_1 (closed circuit reading containing a known supplementary resistance R' adapted for high frequencies), δ_2 (closed circuit with R' cut out) and then in order δ_1, δ_0, δ_1, δ_2, δ_1, δ_0, δ_1, etc. This succession of measurements is necessary in order to be able to eliminate the effects both of

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accidental errors and of the slow displacement of the zero. Calculating the mean deflections $\Delta_1 = \delta_1 - \delta_0$, and $\Delta_2 = \delta_2 - \delta_0$

we get $I_r = K\sqrt{\Delta_2}$ $\quad R = R' \dfrac{\sqrt{\Delta_1}}{\sqrt{\Delta_2} - \sqrt{\Delta_1}}$

from which $h = \dfrac{I_r}{I} \cdot \dfrac{dR\lambda^2 \cdot 10^{-11}}{2 \cdot 4\pi^2 S_r \cos\alpha}$ $\quad (\mu = 1)$

The following is an example of such measurements:—

December 5th, 1917. Station at Fiumicino:
$d = 23 \cdot 2$ km $\quad S_r = 531$ m^2 $\quad \alpha = 0$ $\quad \lambda = 6{,}500$ m.

CALIBRATION OF THERMOGALVANOMETERS.

Resistance of heater = 4 ohms. Applied P.D. = 2·01 volts.

R	δ_0	δ_1	Δ	$I = \frac{V}{R+4} \cdot 10^3$ milliamperes.	$K = \frac{I \text{ (milliamperes)}}{\sqrt{\Delta}}$
500	373	195·5	177·5	3·99	0·300
700	373	282	91	2·86	0·300
900	373·5	318	55·5	2·225	0·299
1,200	373·5	342	31·5	1·67	0·298
1,400	374	451	23	1·43	0·299
1,700	374	358·5	15·5	1·18	0·300
2,000	374·5	362·8	11·7	1·004	0·294
1,000	374·5	329	45·5	2·000	0·297
2,400	374·8	366·8	8	0·837	0·296
					Mean 0·298

MEASUREMENT OF RADIATION.

TIME.	δ_0	δ_1	δ_2
11 h. 34′ 30″	341·5		
		364·0	
			378·2
		364·4	
	341·2		
		364·5	
			378·5
		364·5	
	341·8		
11 h. 37′ 30″	341·5		
		364·5	
			378·4
		364·5	
	341·5		
		364·4	
			378·5
		364·8	
	342·5		

Mean values $\Delta_1 = 13 \cdot 9_5$ $\quad \Delta_2 = 36 \cdot 7_3$ $\quad I = 83 \cdot 78$ A

$R' = 5 \cdot 68$ ohms $\quad R = 9 \cdot 13$ ohms $\quad h = 153 \cdot 7$ m.

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As is known* in the Rome Station two different aerials supported by three wooden trellis masts 218 metres (714 feet) high were tried in succession. They are represented in plan and in general arrangement in Figs. 8 and 8A. The numerical example is taken from the tests on the first aerial shown

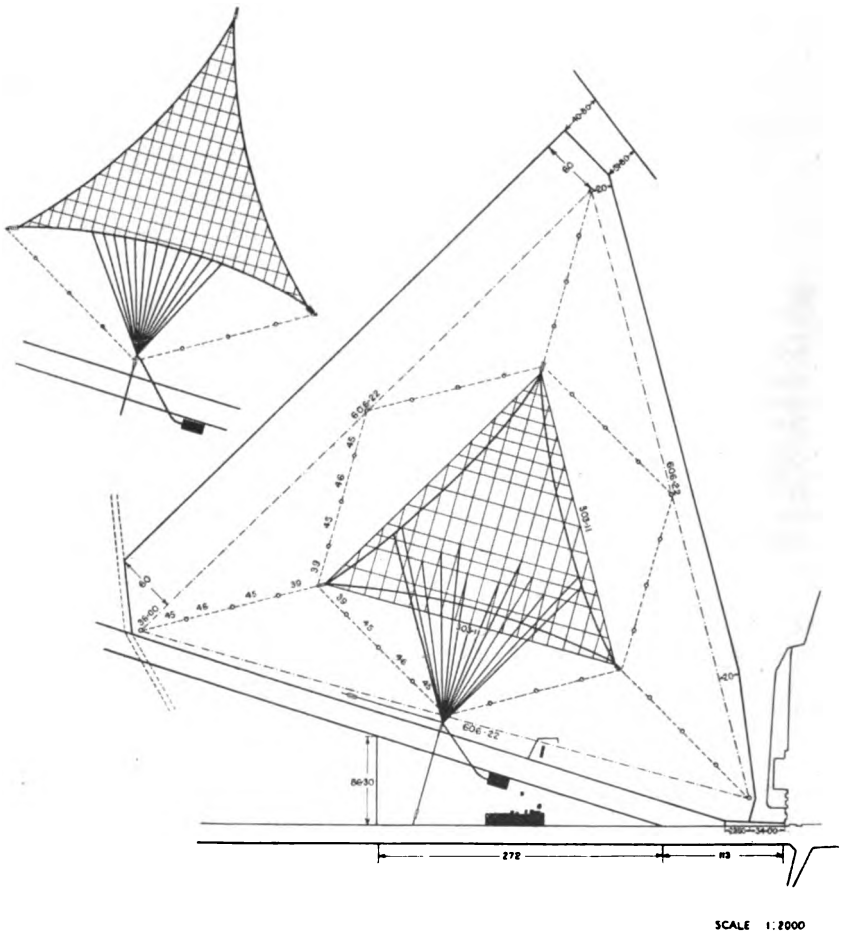

FIG. 8.

* B. Micchiardi, G. Pession, G. Vallauri, "The Rome San Paolo Radiotelegraphic Station." (*L'Elettrotecnica*, 7, pp. 218—224 and 241—244, May 5th and 15th, 1920, and Publication No. 8 of the Electrical and Radiotelegraphic Institute of the Royal Italian Navy.)

[Also: *Proceedings of the Institute of Radio Engineers*, 8, pp. 142—163, April, 1920; RADIO REVIEW Abstracts Nos. 538, July, 1920, and 840, September, 1920.]

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in the top left-hand illustration of Fig. 8, for which we had $\lambda_0 = 2{,}960$ m., $C_s = 9{\cdot}9$ mμF (static capacity). From a large number of tests carried out on this aerial which agreed very well for three wavelengths, we found the following values :—

λ_{metres} =	6,500	8,200	10,150
h_{metres} =	153·2	150·8	149·6

These confirm the theoretical forecast of a small decrease of h with increase of λ. Similar tests were carried out on the second aerial (represented in the bottom right-hand of Fig. 8, for which $\lambda_0 = 2{,}930$ m., $C_s = 11{\cdot}2$ mμF from which we obtained

λ_{metres} =	6,830	8,700	10,860
h_{metres} =	138·4	138·4	138·0

These comparative results, compared with the various values of the current which the Poulsen arc was capable of maintaining in each of the two aerials, allowed of a rational choice between them. (See preceding footnote.*)

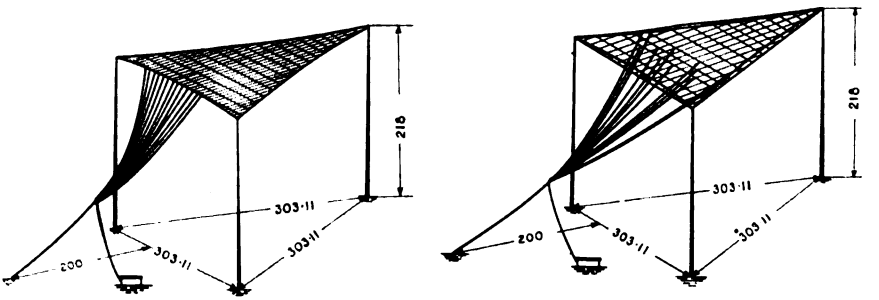

FIG. 8A.

Still more numerous measurements were carried out in January and February, 1918, on the Coltano aerial. The aerial used at that time shown diagrammatically in elevation and in plan by Fig. 9 consisted of thirty wires of which twenty-four were included between the masts and the other six divided into two sets of three and secured to the outside stays. The aerial, moreover, presented the noteworthy feature of being fed at the middle and the plant was still worked by the Marconi spark system (with an asynchronous disc discharger). On this occasion a small measuring plant was used, easily portable and quickly mounted.

The receiving aerial was a single triangular coil, supported by a bamboo dismountable mast of the Marconi field type, 21 metres high (68 feet 10 inches). The mast could be set up and the aerial mounted in a few minutes ; the

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necessary material together with the measuring instruments and the mast was transported in a motor lorry. In the rear cabin of the motor lorry the thermogalvanometer was placed (Fig. 10); on the footboard were placed the variable condenser, the resistances, the coupling inductance, the buzzer, etc.,

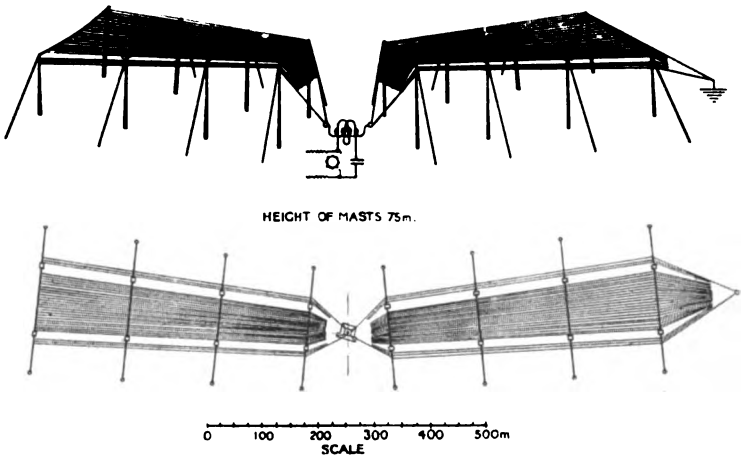

FIG. 9.

so that the operator might stand on the ground and the little lorry be perfectly steady, as is required for the stability of the galvanometer. A black hood supported by the two open rear windows of the lorry came down all round the observer and the footboard which acted as a table for the tests, so as to avoid any air currents and to allow reflection (mirror) reading. The insulation afforded by the rubber tyres of the lorry helped to exclude any risk of the measurements being falsified by the action of any current passing through the galvanometer, under the action of an E.M.F. induced, not in the closed circuit of the aerial, but between this and the earth. The measurement of the aerial resistance was effected by impulse excitation (par. 7), produced by an aperiodic primary containing a cell and a good buzzer. As

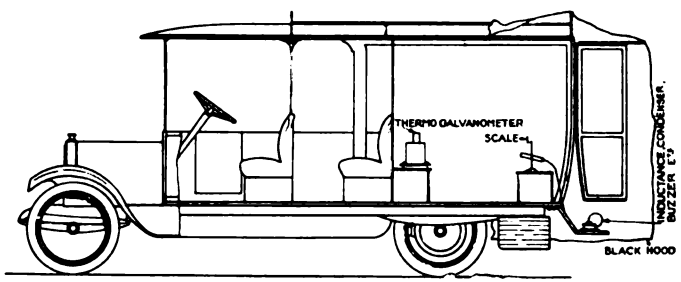

FIG. 10.

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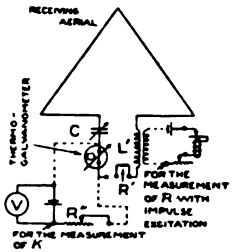

Measurement of the resistance R of the receiving aerial by means of impulse excitation:

$$R = R' \frac{\Delta}{\Delta_2 - \Delta_1}$$

Ditto, with continuous waves and very weak coupling.

$$R = R' \frac{\sqrt{\Delta_1}}{\sqrt{\Delta_2} - \sqrt{\Delta_1}}.$$

(N.B.—When the signals are C.W. they may be used for this measurement.)

Measurement of the constant K of the thermogalvanometer ($R_t = R'' + R_{\text{coils}}$)

$$K = \frac{I}{\sqrt{\Delta}} = \frac{V}{R_t \sqrt{\Delta}}.$$

Calculation of the effective height $h = \frac{I_r}{I_t} \cdot \frac{\lambda d}{S} \cdot L \cdot \frac{\sqrt{\delta_r(\delta_r + \delta_t)}}{4\pi^2 \cos\alpha}$ cms

and for $\delta_t = 0$ (*i.e.*, with undamped oscillations): $h = \frac{I_r}{I_t} \cdot \frac{dR \lambda^2 \cdot 10^{-11}}{2 \cdot 4\pi^2 S \cos\alpha}$ cms.

$\Delta = \delta - \delta_0$ = Deflection of thermogalvanometer $\begin{cases} \Delta_1 = \delta_1 - \delta_0 \text{ with } R' \text{ included} \\ \Delta_2 = \delta_2 - \delta_0 \text{ without } R'. \end{cases}$

λ = Wavelength.

I_t = R.M.S. value of the transmitter current.

I_r = " " " received current.

δ_t = Log. decrement per period of the transmitted oscillations.

δ_r = " " " " " receiving aerial.

d = Distance between the two stations.

L = Total inductance of the receiving circuit in cms.

R = Total resistance of the receiving circuit in C.G.S. units.

S = Total effective (area × turns) of the receiving aerial.

α = Angle between plane of receiving coil and direction of station.

[h, λ, d and S are all in cm. or cm².]

Example — February 6th, 1918: Station Calambrone.

Measurement of the Aerial Resistance.

δ_0	δ_1	δ_2	δ_0	δ_1	δ_2
296			180		
	336			332	
	336	375		296	420
288			175		
	341			316	
	338	388		304	425
286			169		
	346			290	
	348	388		305	410
282			163		
	334	"		320	
		386			393
288	339·7	381·8	171·5	308·3	412·0
	288·0	288·0		171·5	171·5
	$\Delta_1 = 51{\cdot}7$	$\Delta_2 = 93{\cdot}8$		$\Delta_1 = 137{\cdot}8$	$\Delta_2 = 240{\cdot}5$
		51·7			137·8
	$\Delta_2 - \Delta_1 = 42{\cdot}1$			$\Delta_2 - \Delta_1 = 102{\cdot}7$	

$$R = 6{\cdot}12 \frac{51{\cdot}7}{42{\cdot}1} = 7{\cdot}51 \qquad R = 6{\cdot}12 \frac{137{\cdot}8}{102{\cdot}7} = 8{\cdot}21$$

Mean R = 7·86 ohms.

Decrement of the Receiving Aerial.

$$\delta_r = \pi \sqrt{\frac{C}{L}} R.$$

R_1 = 7·86 + 6·12 − 13·98 δ_r' = 0·361.

R_2 = 7·86 δ_r' = 0·203.

Distance from Coltano . . . 10,700 m.

True azimuth with respect to Coltano . 231°

" " of the aerial 50·5°

α . . . . . 0·5°

Base of the triangular aerial . 39·35 m.

Height " " " . 18·20 m.

Area " " " 358 m².

δ_0 δ_1 δ_2 readings of the thermo galvanometer with scale at 1 m, and 4 ohm heater.

R' . . . . . 6·12 ohms.

λ . . . . . 6,300 m.

L' . . . . . 226 μH.

L_{coils} . . . . . 406 μH.

C . . . . . 27·5 mμF.

δ_t . . . . . 0·160

Calibration of the Galvanometer.

V = 1·96

$P_1 + R_g$	$I \times 10^{-3}$	δ_0	δ_1	Δ	$1/\sqrt{\Delta}$
2005	0·990	202 202	239	37	0·163
1505	1·315	200 200	269	69	0·158
1005	1·97	197 197	352	155	0·158
905	2·19	195 194	385	190·5	0·158
805	2·46	188 187	432·5	245	0·157
705	2·81	184·5 185	509	324·8	0·158

K mean = 0·158

Measurement of the Current at the Transmitter and Receiver.

(24 dashes each of 8 secs., with intervals of 22 secs., the first dash serving for tuning)

I_t	δ_0	δ_1	δ_2	Δ_1	Δ_2
126	65 65		107·5		42·5
127	64·5 64·5	82·5		18·0	
132	64 64		108·0		44·0
132	63·5 63	82·5		19·3	
129	62·8 62·8		103·5		40·7
127	62·5 62·0	80·9		18·7	
132	61·7 61·5		104·6		43·0
134	61·0 60·8	79·5		18·6	
133	60·5 60·4		102·8		42·3
135	60·0 59·7	78·5		18·6	
132	59·5 59·3		102·5		43·1
132	59·0 58·8	77·5		18·6	
132	58·5 58·7		99·0		40·4
133	58·5 58·8	78·5		19·7	
126	58·8 59·0		103·0		44·1
125	58·8 58·5	78·2		19·5	
130·4				Δ 18·9	42·8
				I_t 0·687	1·034
				milliamperes	

Calculation of h

$$\frac{1{\cdot}034 \times 10^{-3}}{130{\cdot}4} \cdot \frac{6300 \times 10700}{358} \cdot 406000 \cdot \frac{\sqrt{0{\cdot}203\,(0{\cdot}160 + 0{\cdot}203)}}{4\pi^2} = 4{\cdot}179 \text{ cm.}$$

$$\frac{0{\cdot}687 \times 10^{-3}}{130{\cdot}4} \cdot \frac{6300 \times 10700}{358} \cdot 406000 \cdot \frac{\sqrt{0{\cdot}361\,(0{\cdot}160 + 0{\cdot}361)}}{4\pi^2} = 4{\cdot}438 \text{ cm.}$$

$\therefore h_{\text{mean}}$ = 43·1 m.

FIG. 11.

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the transmitting plant would have been too much endangered by a long duration of spark emission, it was agreed to execute for every series of measurements and at a predetermined hour, twenty-four emissions each lasting eight seconds and separated by pauses of twenty-two seconds duration. A duration of eight seconds was sufficient for the deflection of the thermogalvanometer to attain the steady value. The first emission served to regulate the tuning the others for the measurements.

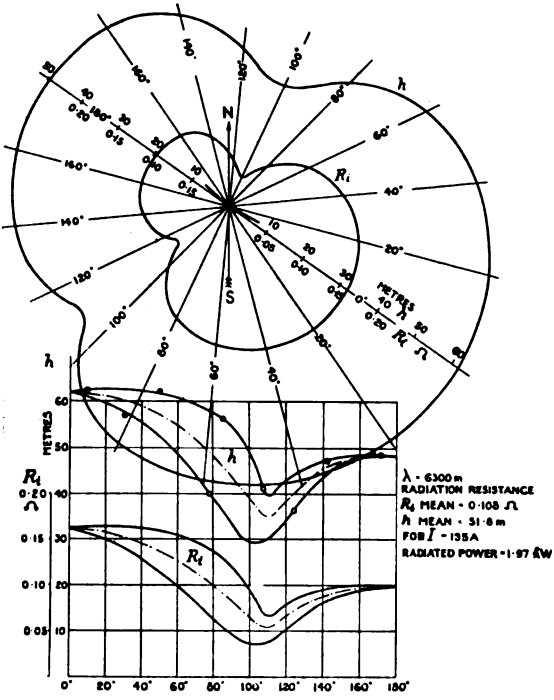

FIG. 12.

The scheme of the circuits, the formulæ and the principal instructions, together with a complete example of measurements and calculations, are reproduced in the table shown in Fig. 11, which was compiled and distributed among the Royal Naval Radiotelegraphic services in February, 1918, and serves as a guide for the current execution of radiation measurements.*

With the appliances described and with a fairly practised staff, it is easy to erect two or even three different stations in a single day. In such a way, for example, we were easily able to determine the values of the height and the radiation resistance of the Coltano aerial we have described, measured in eight azimuth directions. With these data we constructed the polar and Cartesian diagrams of Fig. 12, from which we get (as stated in par. 9) the mean radiation resistance $R_1 = 0{\cdot}108$ ohm and the corresponding height $h = 51{\cdot}8$ m., which may be compared with the height of the masts $h' = 75$ m. (consisting of 45 metres of metal trellis and 30 metres of compound wooden mast).

The diagrams of Fig. 12, the first of their kind if I am not mistaken, which refer to large aerials in active service, present the features of two maxima of different values in the axial direction and two minima in directions angularly

* The particulars given in this table (Fig. 11) have been translated before reproduction, the original chart being in Italian.

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distant 100°—110° from that of the greater of the two maxima. Moreover, the appreciable influence of the fact that the two halves of the aerial are not exactly straight, but form an obtuse angle, is worthy of note. This produces a notable difference between the two halves, in which the radiation diagrams can be divided with respect to the lines of the maxima: The radiation appears remarkably larger on the side of the convex angle than that of the concave angle. Other experiments are now being made which are intended to verify whether at greater distances than those chosen for the experiments of Fig. 12 (distances equal to about 2λ), the effects of absorption or of diffraction would appreciably alter the radiation diagram.

Conclusion.—The object of the present note has been to supply to those who have to undertake the carrying out of the acceptance and the management of radiotelegraphic plants, a guide for carrying out the radiation measurements, which, in their turn, give substantial elements for judging of the efficiency of an aerial as transmitter and receiver of electromagnetic waves. For this purpose the principles are recalled on which the phenomenon of radiation is based, the analytical relations which connect the several elements of the same and which govern the variations are deduced, the approximations introduced in the calculations are discussed, and finally the several experimental methods are set forth, the particulars being stated and illustrated with practical examples which refer to certain typical shapes of aerials excited both by damped as well as by persistent oscillations.

Leghorn,
October, 1920.

The Effect of Modulation Waveshape upon Received Signals.

By A. S. BLATTERMAN.

(*Concluded from page* 151.)

Interrupted Sine Modulation.

This type of modulation is obtained by supplying the plate circuit of a transmitting vacuum tube with alternating voltage at audio frequency instead of the usual D.C. voltage. High frequency energy in this case is radiated only during the positive alternation of the audio plate voltage and the wave train to be considered is therefore that of Fig. 9.

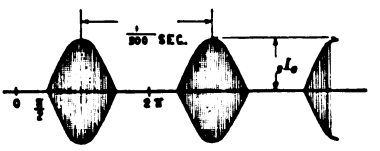

FIG. 9.

The Fourier series for the envelope curve is

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$$i = {}_sI_0\left\{\begin{aligned}&\frac{1}{\pi} + \frac{1}{2}\sin(pt - 90°) - \frac{2}{3\pi}\sin(2pt - 90°) + \\ &\quad + \frac{2}{15\pi}\sin(4pt - 90°) - \frac{2}{35\pi}\sin(6pt - 90°) + \ldots .\end{aligned}\right\}$$

Let us assume that the receiving circuit has a decrement of 0·02, the wavelength 600 metres, the modulation produced from a 500 cycle source; the note at the receiver will be essentially characteristic of 500 cycles. We have

$$\lambda = 600 \text{ m.}$$

$$\omega = 2\pi\ 500{,}000$$

$$p = 2\pi\ 500$$

$$\delta_r = 0{\cdot}02$$

$$S_0 = \frac{1}{\pi}$$

$$S_1 = \frac{1}{2} \qquad \phi_1 = \cos^{-1} 0{\cdot}955 = 17° 20'$$

$$S_2 = -\frac{2}{3\pi} \qquad \phi_2 = \cos^{-1} 0{\cdot}85 = 31° 50'$$

$$S_3 = 0$$

$$S_4 = \frac{2}{15\pi} \qquad \phi_4 = \cos^{-1} 0{\cdot}62 = 51° 40'$$

$$S_5 = 0$$

$$S_6 = -\frac{2}{35\pi}$$

The detecting current is therefore, by (19) proportional to

$$\text{Constant} \times \left\{\frac{\frac{\left(\frac{1}{\pi}\right)^2}{2} + \frac{\left(\frac{1}{2}\times 0{\cdot}955\right)^2}{4} + \frac{\left(\frac{2}{3\pi}\times 0{\cdot}85\right)^2}{4} + \frac{\left(\frac{2}{15\pi}\times 0{\cdot}62\right)^2}{4} + \ldots .}{\frac{\left(\frac{1}{\pi}\right)^2}{2} + \frac{\left(\frac{1}{2}\right)^2}{4} + \frac{\left(\frac{2}{3\pi}\right)^2}{4} + \frac{\left(\frac{2}{15\pi}\right)^2}{4} + \ldots .}\right\}$$

$$= \text{constant} \times \frac{0{\cdot}1208}{0{\cdot}1248} = \text{constant} \times \mathbf{0{\cdot}970} \quad . \quad . \quad . \quad . \quad . \quad (20)$$

The bracketed term of (16b) gives the envelope curve of the received current and this is drawn for the case just considered on Fig. 10, together with the transmitted wave. The distortion owing to phase shift of the side frequencies is clearly evident.*

---

* The lower half of the wave is omitted in this figure for the sake of clearness.

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Rectangular Chopped Modulation.

This type of modulation is produced by such devices as a rotary chopper directly in the sending antenna circuit. The time interval between the pulses, or the periods when the antenna is inactive may be made anything desired according to the construction of the chopper, but we will here consider the particular case wherein the active and inactive intervals

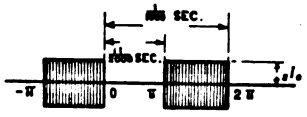

FIG. 11.

are equal, giving the waveform of Fig. 11. The frequency of the pulses will be taken at 1,000 per second and the wavelength and receiver decrement the same as above; that is 600 metres and 0·02 respectively.

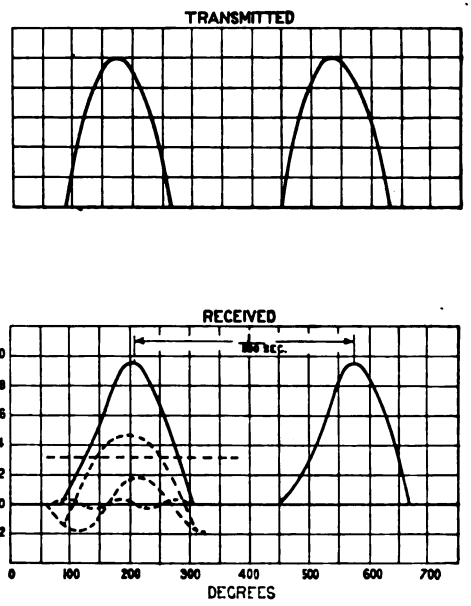

FIG. 10.

The equation of the rectangular envelope curve is, in this case

$$i = {}_sI_0 \left[\frac{1}{2} - \frac{2}{\pi}\sin pt - \frac{2}{3\pi}\sin 3pt - \frac{2}{5\pi}\sin 5pt - \ldots\right]$$

therefore $S_0 = \frac{1}{2}$

$$S_1 = -0{\cdot}637 \qquad \cos\phi_1 = 0{\cdot}847 \qquad \phi_1 = 32°$$
$$S_2 = 0$$
$$S_3 = -0{\cdot}212 \qquad \cos\phi_3 = 0{\cdot}469 \qquad \phi_3 = 62°$$
$$S_4 = 0$$
$$S_5 = -0{\cdot}127 \qquad \cos\phi_5 = 0{\cdot}303 \qquad \phi_5 = 72°\ 20'$$

The factor by which the detecting current is to be measured is, therefore, by (19).

$$\text{Constant} \times \mathbf{0{\cdot}829} \ldots\ldots\ldots \quad (21)$$

The waveform of received current modulation is contrasted with that of the transmitter in Fig. 12. The distortion in this case is seen to be very marked.

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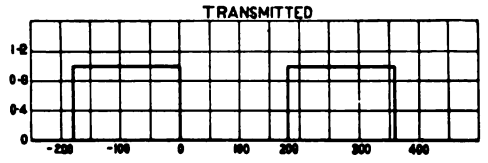

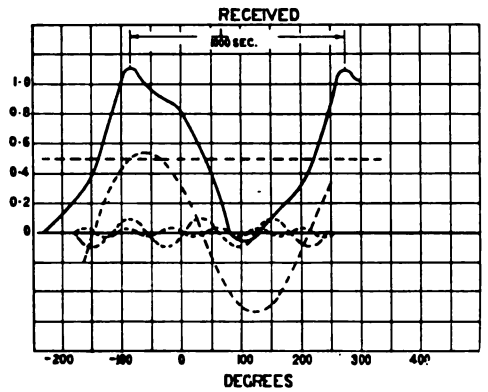

FIG. 12.

By comparing (20) and (21) it is seen that the rectangular modulation with equal antenna current at the transmitter should give weaker signals than the interrupted sine modulation in the ratio 829 to 970.

Spark Signals (Logarithmic Modulation).

In this case the transmitter

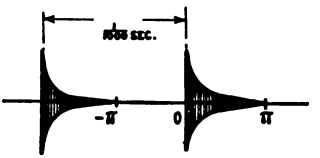

FIG. 13.

current has approximately the waveform of Fig. 13.

Assuming again $\lambda = 600$ metres, spark frequency 1,000 per second, receiver decrement 0·02, transmitter decrement 0·1, the equation to the envelope curve of Fig. 13 is

$$i = {}_sI_0 [S_0 + S_1 \sin (pt + \theta_1) + S_2 \sin (2pt + \theta_2) + \\ + S_3 \sin (3pt + \theta_3) + \ldots .]$$

where

$S_0 = 0{\cdot}02$	
$S_1 = 0{\cdot}0398$	$\theta_1 = 82° 50'$
$S_2 = 0{\cdot}0387$	$\theta_2 = 75° 55'$
$S_3 = 0{\cdot}0374$	$\theta_3 = 69° 50'$
$S_4 = 0{\cdot}0357$	$\theta_4 = 63° 15'$
$S_5 = 0{\cdot}0339$	$\theta_5 = 57° 55'$
$S_6 = 0{\cdot}0318$	$\theta_6 = 53°$
$S_7 = 0{\cdot}0299$	$\theta_7 = 48° 40'$
$S_8 = 0{\cdot}0282$	$\theta_8 = 45°$
$S_9 = 0{\cdot}0264$	$\theta_9 = 41° 30'$
$S_{10} = 0{\cdot}0259$	$\theta_{10} = 38° 30'$

The envelope curve of received current according to (16) is then

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$$i_r = \frac{k\,{}_sI_0}{r_r}\{S_0+[S_1\cos\phi_1]\sin(pt+\theta_1-\phi_1)+[S_2\cos\phi_2]\sin(2pt+\theta_2-\phi_2)+ \\ +[S_3\cos\phi_3]\sin(3pt+\theta_3-\phi_3)\ldots.\}$$

where

$\phi_1 = 32°\ 10'$	$\cos\phi_1 = 0{\cdot}847$
$\phi_2 = 51°\ 20'$	$\cos\phi_2 = 0{\cdot}625$
$\phi_3 = 62°$	$\cos\phi_3 = 0{\cdot}469$
$\phi_4 = 68°\ 20'$	$\cos\phi_4 = 0{\cdot}37$
$\phi_5 = 72°\ 20'$	$\cos\phi_5 = 0{\cdot}303$
$\phi_6 = 75°\ 10'$	$\cos\phi_6 = 0{\cdot}2565$
$\phi_7 = 77°\ 10'$	$\cos\phi_7 = 0{\cdot}2215$
$\phi_8 = 78°\ 45'$	$\cos\phi_8 = 0{\cdot}195$
$\phi_9 = 80°$	$\cos\phi_9 = 0{\cdot}174$
$\phi_{10} = 81°$	$\cos\phi_{10} = 0{\cdot}157$

The measure of received signal strength (equation 19) is therefore

$$\text{Constant} \times \frac{0{\cdot}000824}{0{\cdot}00295} = \text{constant} \times \mathbf{0{\cdot}279} \ldots. \quad (22)$$

This calculation is the result of using ten terms of the Fourier's series. On account of the fact that the coefficients in the series for the transmitted current decrease much more slowly than those for the received current and are still appreciable at the tenth term, the factor just determined is somewhat high.

Fig. 14 shows the envelope curve of transmitting and received currents and the distortion is again plainly evident. It is to be noted that in this particular case of logarithmic transmitter modulation the mean square received antenna current as well as the shape of the envelope curve of same may be calculated by Bjerknes's formulæ, commonly stated in text books. Results obtained by these formulæ agree exactly with those given in this paper provided a sufficient number of terms are used in the Fourier's series in the latter case.

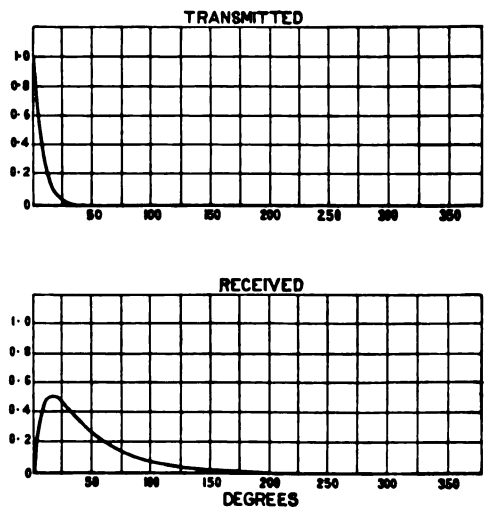

FIG. 14.

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Double Rectified Sine Modulation.

This type of modulation is shown on Fig. 15 and is produced in practice by supplying the plate circuit of an oscillating vacuum tube from the source shown on Fig. 16A, or a pair of oscillating tubes may be used in some such circuit as that of Fig. 16B. In order to compare this case with those previously treated we may again take $\lambda = 600$ metres, supply frequency 500 cycles,

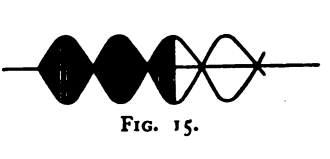

FIG. 15.

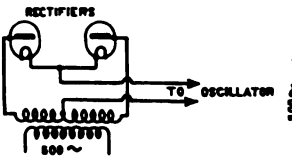

FIG. 16A.

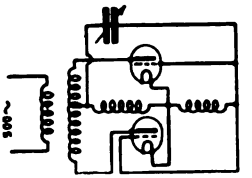

FIG. 16B.

receiver decrement 0·02. The received note will be characteristic of 1,000 cycles.

The equation of the transmitter current is

$$_si = \frac{2}{\pi} {}_sI_0 \left\{ 1 - \frac{2}{3}\sin(2pt - 90°) + \frac{2}{15}\sin(4pt - 90°) - \right.$$
$$\left. - \frac{2}{35}\sin(6pt - 90°) + \ldots . \right\}$$

and we get

$S_0 =$	0·636		
$S_1 =$	0		
$S_2 =$	− 0·425	$\phi_2 = 31° 50'$	$\cos \phi_2 = 0·85$
$S_3 =$	0		
$S_4 =$	0·085	$\phi_4 = 51° 40'$	$\cos \phi_4 = 0·62$
$S_5 =$	0		
$S_6 =$	− 0·0364	$\phi_6 = 62°$	$\cos \phi_6 = 0·47$

The reception factor by (19) becomes

$$\text{Constant} \times \frac{0·235866}{0·249837} = \text{constant} \times \mathbf{0·944}.$$

It has been pointed out previously that the detecting telephone currents can only be taken proportional to mean square antenna current when the latter is completely modulated; when the modulation is not complete a correction factor must be applied. This correction factor for a sine modulation is given on Fig. 7.

The present case is one in which the modulation is incomplete since the received current is (according to (16))

$$_ri = \frac{k\,{}_sI_0}{r_r} \left\{ 0·636 - 0·361\sin(2pt - 121° 50') + 0·0527\sin(4pt - 141° 40') - \right.$$
$$\left. - 0·0171\sin(6pt - 152°) + \ldots . \right\} \sin \omega t$$

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Neglecting the small amplitude harmonics above the second, the percentage modulation of received current can be taken as approximately equal to

$$k = \frac{0{\cdot}361}{0{\cdot}636} = 0{\cdot}567$$

giving as correction factor from Fig. 7 the quantity 0·696. Applying this correction, the quantity to be used as measure of the detecting current becomes

$$\text{Constant} \times 0{\cdot}944 \times 0{\cdot}696 = \text{Constant} \times \mathbf{0{\cdot}657} \quad . \quad . \quad . \quad (23)$$

Sine Modulation.

This type of modulation has already been calculated above in connection with the explanation of receiving radio circuit distortion. It is shown again on Fig. 17.

FIG. 17.

For the same wavelength and decrement as above and 1,000 cycle modulation the received current is

$$_ri = \frac{k_r I_0}{r_r}\left\{0{\cdot}5 + 0{\cdot}425 \sin\left(pt - 31° 50'\right)\right\} \sin \omega t$$

The percentage modulation at the receiver is $k = 0{\cdot}85$ giving correction factor from Fig. 7, $\sigma = 0{\cdot}902$ and the proportionality factor for detecting current (19) is therefore

$$\left(\frac{\frac{0{\cdot}5^2}{2} + \frac{0{\cdot}425^2}{4}}{\frac{0{\cdot}5^2}{2} + \frac{0{\cdot}5^2}{4}}\right) 0{\cdot}902 = \mathbf{0{\cdot}818} \quad . \quad . \quad . \quad . \quad . \quad (24)$$

MORE ACCURATE TREATMENT.

The foregoing treatment has neglected the distortion effects of the detector. The latter, as has been pointed out, tends to introduce changes in the amplitudes of the harmonics present in the envelope curve of received antenna current on account of its non-linear, imperfect rectification characteristics. This affects the quality as well as the intensity of the signal somewhat. The following formulæ permit calculations to be made of the detected (rectified) telephone current and signal strength upon the assumption that the detector characteristic is representable by the equation

$$i = a_1 e + a_2 e^2.$$

As has been shown, e has, in general, the form

$$e = U\left\{A + B_1 \sin(pt + \alpha_1) + B_2 \sin(2pt + \alpha_2) + \right.$$
$$\left. + B_3 \sin(3pt + \alpha_3) + \ldots .\right\} \sin \omega t$$

Substituting this in the characteristic equation, gives for the audio frequency

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detecting current, after dropping all terms of radio and zero frequencies and making certain transformations

$$I = \frac{a_2}{2}\Big\{2AB_1 \sin(pt + \alpha_1) + B_1B_2 \cos[pt + (\alpha_1 - \alpha_2)] + \\ + B_2B_3 \cos[pt + (\alpha_2 - \alpha_3)] + \ldots. \\ + 2AB_2 \sin(2pt + \alpha_2) + B_1B_3 \cos[2pt + (\alpha_1 - \alpha_3)] - \\ - \frac{B_1^2}{2}\cos(2pt + 2\alpha_1) + B_2B_4 \cos[2pt + (\alpha_2 - \alpha_4)] + \\ + B_3B_5 \cos[2pt + (\alpha_3 - \alpha_5)] + \ldots. \\ + 2AB_3 \sin(3pt + \alpha_3) - B_1B_2 \cos[3pt + (\alpha_1 + \alpha_2)] + \\ + B_1B_4 \cos[3pt + (\alpha_1 - \alpha_4)] + B_2B_5 \cos[3pt + (\alpha_2 + \alpha_5)] + \ldots. \\ + 2AB_4 \sin(4pt + \alpha_4) - \frac{B_2^2}{2}\cos(4pt + 2\alpha_2) - \\ - B_1B_3 \cos[4pt + (\alpha_1 + \alpha_3)] + B_1B_5 \cos[4pt + (\alpha_1 - \alpha_5)] + \\ + B_2B_6 \cos[4pt + (\alpha_2 - \alpha_6)] + \ldots. \\ + 2AB_5 \sin(5pt + \alpha_5) - B_2B_3 \cos[5pt + (\alpha_2 + \alpha_3)] + \\ + B_1B_6 \cos[5pt + (\alpha_1 - \alpha_6)] + B_2B_7 \cos[5pt + (\alpha_2 - \alpha_7)] + \ldots. \\ + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\Big\} U^2$$

In this expression terms of the same frequency have been grouped together, and the various frequencies corresponding respectively to pt, $2pt$, $3pt$, $4pt$, etc. follow each other in sequence. It will be seen that each of the series giving the component current of a particular frequency has the form

$$I_k = [M_1 \sin(kpt + \psi_1) + M_2 \cos(kpt + \psi_2) + M_3 \cos(kpt + \psi_3) + \\ + M_4 \cos(kpt + \psi_4) + \ldots.]Y$$

which may be otherwise written in the form

$$\left.\begin{aligned} I_k &= \sqrt{\{M_1^2 + M_2^2 + M_3^2 + M_4^2 + M_5^2 + \ldots. \\ &\quad + 2M_1M_2 \sin(\psi_1 - \psi_2) + 2M_1M_3 \sin(\psi_1 - \psi_3) + \\ &\quad + 2M_1M_4 \sin(\psi_1 - \psi_4) + \ldots. \\ &\quad + 2M_2M_3 \cos(\psi_2 - \psi_3) + 2M_2M_4 \cos(\psi_2 - \psi_4) + \\ &\quad + 2M_2M_5 \cos(\psi_2 - \psi_5) + \ldots. \\ &\quad + 2M_3M_4 \cos(\psi_3 - \psi_4) + 2M_3M_5 \cos(\psi_3 - \psi_5) + \\ &\quad + 2M_3M_6 \cos(\psi_3 - \psi_6) + \ldots. \\ &\quad + \ldots.\}} \sin(kpt + \gamma_k) \cdot Y \\ &= [\beta_k \sin(kpt + \gamma_k)]\, Y \end{aligned}\right\} \quad (25)$$

where

$$\gamma_k = \tan^{-1}\frac{M_1 \sin\psi_1 + M_2 \cos\psi_2 + M_3 \cos\psi_3 + \ldots.}{M_1 \cos\psi_1 - M_2 \sin\psi_2 - M_3 \sin\psi_3 - \ldots.}$$

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The expression (25) may be used to calculate the amplitude and phase (γ) of any of the constituent frequencies in the telephone current; and the effective value of the actual distorted telephone current wave is

$$_aI_e' = Y\sqrt{\sum_{k=1}^{k=n}\frac{\beta_k^2}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (26)$$

In making comparisons of this telephone current for different types of modulation it must be noted that the constant Y is proportional to the square of the maximum or peak value $_aI_0$ of transmitted current, and if the comparisons are to be made on the basis of equal R.M.S. transmitter currents in each case the equation (15) must be used as a divisor for the reduction of the values given by (26). For comparison purposes therefore we employ in each case the formula

$$_aI_e = \text{constant} \times \sqrt{\sum_{k=1}^{k=n}\frac{\beta_k^2}{2}} \cdot \frac{1}{\left(\frac{S_0^2}{2}+\frac{S_1^2}{4}+\frac{S_2^2}{4}+\frac{S_3^2}{4}+\ldots\right)^2} \quad . \quad (27)$$

The numerical manipulation may become a little cumbersome in some cases. In order, however, to show the order of magnitude of deviation in the ratio of telephone currents for different modulation waveshapes, determined first upon the basis of M.S. antenna currents and then by the more accurate method where the detector distortion is taken into account, the formulæ (25) and (27) have been applied to two of the cases previously treated, viz.,

(*a*) Chopper modulation,

(*b*) Sine modulation,

with the results shown in the following tables :—

	Chopper modulation.	Sine modulation.
Fundamental	0·542	0·425
2nd harmonic	0·093	0·0904
3rd „	0·0995	0·0
4th „	0·0414	0·0
5th „	0·0385	0·0
$S_0^2/2 + S_1^2/4 + S_2^2/4 + \ldots$	0·242	0·1895
$\frac{_aI_e}{\text{Constant}} = \sqrt{\frac{\Sigma_1^n \beta_k^2/2}{(S_0^2/2 + S_1^2/4 + S_2^2/4 \ldots .)^2}}$.	1·615	1·640

The signal strength ratios,* when calculated by the approximate and accurate methods are then

* The term "signal strength" is used somewhat loosely. Obviously the discussion concerns the effective telephone currents.

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	By approximate method.	By accurate method.
Ratio $\frac{\text{Chopped}}{\text{Sine}}$.	$\frac{0{\cdot}829}{0{\cdot}818} = 1{\cdot}01$	$\frac{1{\cdot}615}{1{\cdot}640} = 0{\cdot}984$

and are seen to differ by less than 3 per cent. It is therefore fair to assume not only that the figures arrived at previously for the various types of modulation may be used for comparison of the effectiveness of these types among themselves, but also that the approximate method of calculation gives a way of comparing different modulation waveshapes, as far as signal strength is concerned, which is sufficiently accurate for all practical purposes.

SUMMARY AND DISCUSSION OF RESULTS.

It has been shown that the waveshape of modulation has *per se* an appreciable effect on the intensity of received signals. It has also been shown that different waveshapes of modulation are differently distorted, thus differently affecting the quality or timbre of the received note. Several types of modulation have been compared numerically on the basis of equal R.M.S. transmitting antenna currents in each case. The relative signal strengths have been calculated and formulæ for calculating the distortion have been given. In several cases the distortion has been shown graphically.

Two methods for investigating the problem have been presented. (*a*) An approximate method wherein the signal strength has been based on the square of the received antenna current and (*b*) a more accurate method in which the actual telephone current has been calculated. It has been shown that these two methods agree closely with one another as regards the determination of strength of signal.

Distortion occurs at two points in the receiving circuits, first in the tuned radio frequency circuits and secondly on account of the non-linear imperfect rectification characteristic of the detector. The first distortion is caused by the fact that the receiving antenna system is tuned to the carrier frequency of transmission. The side frequencies resulting from the modulation at the transmitter are therefore more or less out of tune. For this reason they are suppressed and shifted in phase to a greater or less degree, depending upon their divergency from the carrier frequency. When the carrier and the side frequencies are recombined at the receiver they therefore give a waveshape quite different from that originally transmitted.

The results of the investigation concerning the five types of modulation treated may be summarised in the following table. In this table the signal strength for a 100 per cent. pure sine modulation at the transmitter is taken as unity. The strengths of signals for other modulations are referred to this sine modulation as basis. The R.M.S. transmitting antenna current is

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assumed to be the same in each case, and the figures given are those determined by the approximate method described.*

Type of modulation.		Audibility.
Pure sine	(1,000 cycles) .	1·00
Spark	(1,000 cycles) .	0·341
Interrupted sine	(500 cycles) .	1·187
Double rectified sine	(1,000 cycles) .	0·802
Chopper	(1,000 cycles) .	1·014

In regard to the accurate method of calculating the phenomena it should be noted that this is based on the assumption that the detector characteristic can be represented by the equation

$$i = a_1 e + a_2 e^2.$$

This equation is very nearly correct when the load in the output circuit of the detector is pure resistance. If the load has appreciable reactance this reactance will obviously be different for each constituent frequency of the modulation wave and the coefficients in the equation are thus no longer, strictly speaking, constant. The error in assuming that the coefficients are fixed, however, is not serious and so greatly simplifies the analytical treatment of the problem, that it is believed to be justifiable.

The formulæ presented indicate that for given R.M.S. antenna current at the transmitter the strength of signal increases with decrease in the pitch of the transmission note. This, of course, takes no account of variation in sensitivity of the telephone receiver or the ear with changes in frequency which may to some extent alter this conclusion. The high value of signal strength for the 500 cycle, interrupted sine modulation is accounted for, at least in part, by the fact that the other modulations are calculated for 1,000 cycle note.

The comparatively low efficiency of the spark transmitter is noteworthy. Completely modulated sine transmission or the chopper give, theoretically, nearly three times as much telephone current.

Signal Corps Radio Laboratories,
New Jersey, U.S.A.

A New Design of Aerial Insulator.

The output of a high-power radio station may be seriously limited by inadequate insulation of the aerial wires from the cables by which they are supported. It has been the custom in some recently-built high-power

* These results are determined for a receiver decrement of 0·05. For higher decrements the differences indicated will be reduced, *i.e.*, there is less difference between the various strengths of signals. The waveshape of modulation is less important.

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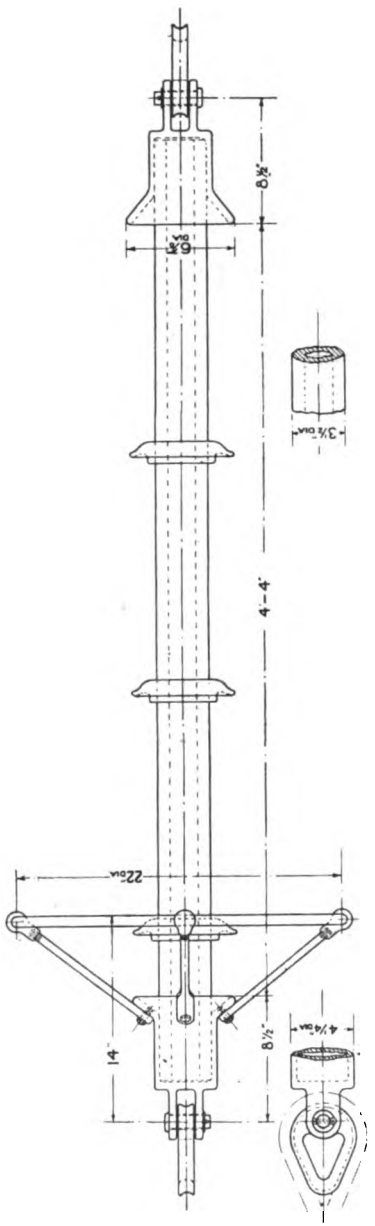

Diagram of new H. T. Aerial Insulator.

stations to employ strings of disc insulators of the type customarily used on high-tension overhead power distribution lines, but it has been found that these have certain disadvantages at high frequencies, chief amongst which are their comparatively high capacity, and the unequal distribution of the high-frequency voltage along the string. At the high-power station erected at Rome during the War as many as eighteen of these insulators were used in series. At the Horsea station several units of this type are employed, together with several others as well as one or more granite blocks—all in series.

As a result of a considerable amount of experimental work carried out by Mr. C. F. Elwell and others, Messrs. Bullers, Ltd., of Hanley, Staffs., have developed a new pattern of high-voltage insulator which is especially suitable for use on the aerials of high-power stations, although it will doubtless also have other important applications as well. The insulator consists of a long porcelain tube to the ends of which metal caps are cemented. The overall length of the insulator between the end shackles is 5 feet 9 inches, while the length of porcelain between the metal caps is 4 feet 4 inches. The lower end of the upper metal cap is belled out as shown in the accompanying drawing, so as to drain off the water from the surface of the porcelain. The lower cap is fitted with a metal ring 22 inches diameter—of $\frac{3}{4}$-inch diameter mild steel rod—to form a flux ring to ensure a more uniform distribution of the electrostatic flux lines at the high-voltage end of the insulator. Porcelain drip rings are also cemented to the insulator at several points along its length, and help to further increase the insulation resistance. When tested electrically under ordinary alternating voltages it has not been found possible to produce a breakdown, even

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when the insulator was at the same time subjected to a heavy precipitation of artificial "rain." With about 120,000 volts between the ends of the insulator when subjected to rain, the current flowing along the surface was less than 1 milliampere.

Before being put into service all such insulators are subjected to a tensile test of 10,000 lbs., while tests to destruction have indicated an average breaking stress of 7½ to 8 tons. When fracture occurs, it is found that there are no indications of flaws in the porcelain, but it always takes place where the cross-section is somewhat reduced at one of the serrations at the end. The caps do not pull off under this load.

The electrical capacity of the insulators is extremely small, so that the capacity currents flowing through the insulator when subjected to high-frequency stresses should also be small, resulting in less deterioration of the porcelain. The weight of a complete insulator is about 95 lbs., as compared with approximately 240 lbs. for one of the strings of eighteen suspension type insulators. The cost is also less.

Insulators of this new type have been installed at Honolulu, San Francisco, and other large American radio stations, while they have also been put into service at the recently constructed Lafayette station at Croix d'Hins. These insulators will also be used at the new Post Office stations being erected at Northolt, Leafield, and Cairo.

The leading dimensions of the insulators are indicated in the accompanying drawing, which also shows the method of attaching the metal flux ring.

Arc *versus* Alternator for High Power Work.

In a recent issue of *Le Génie Civil* an article by A. Bidault des Chaumes discusses the equipment proposed for the high-power station to be erected near Paris.*

In the course of the article the author discusses the relative merits of arcs and high-frequency alternators for high-power stations and in connection with the decision to instal high-frequency alternators at the new station he says:

It now seems certain that the arc systems which have rendered incontestable service in the past will gradually disappear from future installations on account of their numerous inconveniences. This assertion is justified by the following remarks:

In the first place the oscillations set up by the arc are more or less irregular and the useful wave is accompanied by many harmonics which cause interference at receiving stations within a considerable area round the transmitter. Thus the emission from the arc station at the Eiffel Tower possesses many harmonics corresponding to short waves of the order of 300, 600, 1,200 metres, etc., in addition to the fundamental wave of 7,000 to 10,000 metres wavelength. These harmonics which are constantly varying interfere

* See Abstract No. 1639 in this issue; also pp. 125—133 in our last issue.

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considerably with reception at stations which are accidentally tuned to one or other of these frequencies, even when the receiving stations are as much as 200 km from the Eiffel Tower.

The arc station at Salonica may also be quoted as a further example. This station uses a normal wavelength of 6,300 metres and a harmonic of 900 metres can be heard at distances of 100 or more kilometres, while it is even detectable at Crete 300 km from the transmitting station.

The usual process of signalling with arc transmitters consists in slightly varying the wavelength of the oscillations to the extent of from 2 to 3 per cent. in the intervals between the signals. A transmitting station thus radiates two waves with the same power and this fact is particularly harmful at the present time when we are trying to reduce the troubles of receiving stations arising from unwanted transmissions and the multiplicity of communications now necessary. This question will be brought up at the next International Conference and it is practically certain that the suppression of the harmful spacing wave will be rendered obligatory. This suppression, relatively easy in the case of small and medium-power stations, presents considerable difficulty when the power exceeds about 50 kW, while it becomes still more difficult as the power is further increased. In practice no high-power arc at present operates with such a system and the station at Croix d'Hins which is the most recent high-power arc station uses the compensation wave for signalling.

The decomposition of the hydrocarbon atmosphere round the arc which is indispensable to its operation gives rise to sooty deposits in the interior of the arc chamber, the removal of which necessitates frequent and long cleaning operations, so that it is essential to instal at least two arc converters in a normal installation, one being in service while the other is being cleaned. If the service is to be a continuous one a third arc is also necessary as a spare. Thus the power installed in the station is for a commercial service three times that which can be utilised at any time, while further a skilled staff is necessary to carry out the cleaning operations and the replacements of the cathodes, etc.

The irregularities in the arc oscillations give rise to excess voltages which endanger the life of the insulators, while when the compensation wave is used for signalling the insulators are practically always under electrical stress.

The preceding remarks are of a general nature and applicable to all arc stations, but the following refer principally to commercial equipments. Firstly, like the valve transmitter, the efficiency of the arc is low, the maximum theoretically possible being 50 per cent. In practice, the efficiency hardly exceeds 40 per cent. when the arc is carefully adjusted, while if this is not done it falls still lower.

The true overall efficiency is also influenced by the fact that the energy is radiated during the spacing periods while even if a non-radiating artificial aerial is used for the spacing wave the same energy is still wasted as heat in that circuit.

For the successful handling of commercial traffic high-speed methods of

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signalling are necessary. The methods of keying usually employed with arc transmitters seriously limit the transmission speed since large and irregular currents must be interrupted. When the power of the installation is greater than about 50 kW complicated arrangements become necessary involving a multiplication of the number of places where the circuit is broken. Such arrangements prevent the attainment of speeds approaching 100 words per minute such as are possible with other systems. As a matter of fact the large arcs working with America do not transmit at a greater speed than sixty words per minute and even this is not attained without detriment to the quality of the emission. The automatically transmitted signals from Annapolis for example are irregular and often unreadable, while on the other hand those received at the same time from Marion and from New Brunswick which use high-frequency machines (on less power than used in the arcs at Annapolis) are always clear and regular.

Practically the only advantage in favour of the arcs is the ability to change rapidly the wavelength over a considerable range, but the maximum power output is only obtainable on a given wavelength and falls off rapidly when departures are made from this optimum wavelength. High-frequency alternators now allow of a sufficient range of wavelengths (from 1 to 1·5) by means of rapid change-over arrangements. Large wavelength changes are practically only required for military stations, but for commercial services they are not necessary, as if each station uses a large number of wavelengths, the resulting troubles would interfere with the general handling of traffic.

The Physical Society's Exhibition.

A Description of the Exhibits (*continued from page* 153).

MESSRS. MARCONI'S WIRELESS TELEGRAPH CO., LTD., had a working exhibit of their latest pattern of Marine Direction Finder, known as Type 11a. The general arrangement of this instrument is the same as the earlier pattern (Type 11) manufactured by this firm, but with the addition of a special "sense" indicator to show which of the two directions given by the ordinary readings is the correct one.

The action of "sense" finding in this apparatus is illustrated in the simplified diagram of connections shown in Fig. 5.

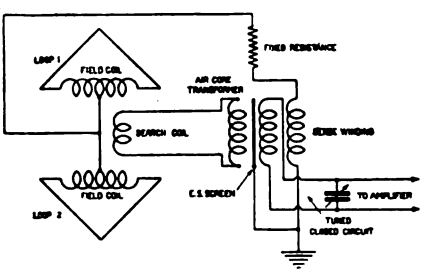

FIG. 5.

The tuned closed circuit from which the signals pass to the amplifier and telephones is influenced by two independent windings of an air core transformer. The first winding is connected to the search coil and thus has currents induced in it which vary in strength according to the position of the search coil with regard to the direction from which the incoming signals are being

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received. This is the ordinary direction finding effect. The second winding is connected on one side to earth and on the other to the common mid-point of both loops through a fixed resistance of a special value. It thus forms part of a simple open aerial-earth circuit and has induced in it currents which are independent of all directional effects and remain constant in value for all positions of the search coil.

The combination of these two effects on the secondary of the transformer —that is on the tuned circuit—produces a resultant current which varies in strength as the search coil is turned, but only rises to a maximum or dies to a minimum for *one* position of the search coil, which is determined by the actual direction in which the station lies.

It will be found that this maximum and minimum is not sharp enough for accurate results. In practice, therefore, the earlier method of direction finding is carried out as a preliminary operation. The operation of " sense " finding as described above being then resorted to as a method of determining which of the two diametrically opposed bearings obtained by the first operation is the correct one.

A special demonstration was also given by PROFESSOR C. L. FORTESCUE and DR. BRYAN illustrating some of the uses of a thermionic valve, for generating oscillations and other purposes. This demonstration was improvised at relatively short notice from ordinary laboratory apparatus, a few valves, a three-valve note magnifier and a loud speaking telephone. None of the apparatus was especially designed or made for the demonstration.

1. Characteristics of the Valves.

Apparatus was shown in which a spot of light was given two motions at right angles, one proportional to the current and the other to the applied

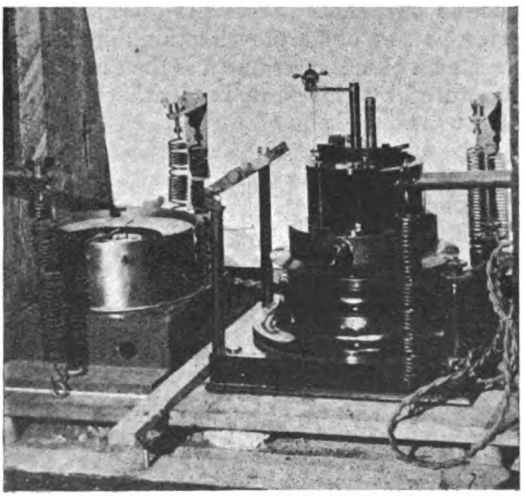

FIG. 6.

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potential difference. By this means the characteristic curves and contour surfaces may be traced out in a minimum of time. Fig. 6 shows the arrangement of the two instruments and mirrors.

2. The use of the Valve as an Audible-frequency Generator.

A valve was shown generating alternating currents of from about 400 to 20,000 cycles per second. A very simple direct coupled circuit is used and the currents are made audible by means of a loud speaking telephone receiver.

3. The use of the Valve for Alternating Current Bridge Measurements.

A capacity bridge was shown in operation, the actual measurement being that of the effective resistance of a 60-volt dry battery. The audible-frequency valve generator just previously described was used and in order to render the sound audible to those present in the room a three-valve transformer coupled amplifier was connected up to a loud speaking telephone. The particular type of bridge chosen accentuates the effect of harmonics and combined with the amplifier shows the valve at its best and its worst. The bridge was balanced on the fundamental to about one part in 3,000.

4. The use of the Valve as a High Frequency Generator to illustrate the principles of heterodyne reception as used in wireless telegraphy.

For this purpose two valve sets were used, one representing the transmitting station and one the receiving station. At the latter the valve was used also as the detector, and by means of the amplifier and loud speaking telephone the incoming signals from the transmitter were rendered audible to the whole room. Several interesting experiments on beat reception were shown, one employing the beat principle twice and showing a degree of constancy of frequency of the oscillations generated of a few parts in 200,000.

5. An Experiment with Modulated Continuous Waves.

Mathematical theory shows that if a pure continuous wave of frequency f_1 is modulated in an irregular but cyclical manner at frequency f_2 then the resulting wave is made up of a series of waves of frequency $f_1, f_1 + f_2, f_1 - f_2, f_1 + 2f_2, f_1 - 2f_2$, etc.. The wave generated by the high frequency transmitter described in the previous paragraph was modulated at a frequency of about 20,000 cycles by means of the audible-frequency generator and the presence of the waves of frequency $f_1 + f_2, f_1 - f_2$, etc., was shown by means of the heterodyne receiver.

Notes.

Personal.

At the annual election of officers recently held by the Institute of Radio Engineers, New York, **Mr. E. F. W. Alexanderson** was elected President of the Institute for the year 1921. Mr. Alexanderson is chief engineer of the Radio Corporation of America and consulting engineer of the General Electric Company of Schenectady. **Foulton Cutting** was elected Vice-President; **A. N. Goldsmith**, Secretary; and **W. F. Hubley**, Treasurer. [2373]

Commander **C. P. Edwards**, O.B.E., A.M.E.I.C., the Director of Radiotelegraphs of the

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Canadian Radio Service, has been elected Chairman of the Ottawa branch of the Engineering Institute of Canada. [1736]

Lieutenant **R. V. Ridges**, R.N.C.V.R., M.B.E., who was fleet wireless officer at Halifax during the war, has joined the engineering staff of the Marconi Wireless Telegraph Co. of Canada, Ltd., and is now stationed at the Montreal headquarters. [2361]

Mr. **C. V. Logwood**, who has been on the Pacific coast during the past few months, is returning to continue research work with the de Forest Company in New York. [2356]

W. R. Whitney, Director of the Research Laboratory, General Electric Company, Schenectady, N.Y., was awarded the Perkin Medal on January 14th by the American Section of the Society of Chemical Industry. Dr. Whitney received this honour for his many inventions in chemistry. [2239]

Wireless Services, etc.

WIRELESS TRAFFIC BETWEEN ENGLAND AND GERMANY.—To improve wireless traffic between England and Germany the dispatch of wireless telegrams for the public has been begun recently. Stonehaven is the sending station on this side and the main telegraph office in Berlin acts as the German station. The charges are the same as the cable tolls. [2183]

In view of the existence of several wireless telegraph services with the Continent auxiliary to and at the same rates as those for the ordinary cables, the Postmaster-General notifies that he reserves the right to use these services for urgent, ordinary, or Press telegrams, except in cases where the original forms are marked thus " by wire." [2182]

WIRELESS SERVICE BETWEEN GERMANY AND BULGARIA.—A wireless service has been opened between Konigswusterhausen and Sofia at the same rates as wire communication, viz. 1.15 M. for ordinary and 0.60 M. for Press messages. [2338]

METEOROLOGICAL RADIO TELEGRAMS.—Commencing December 1st last, the Hungarian station of Csepel transmits daily at 11.30 (Central European time) the Bulletin of the Meteorological Institute of Budapest. [2330]

On December 16th last the Mayor of New York officially opened the radiotelegraph service of the Inter-city Radio Communication Company between the cities of New York, Cleveland, Detroit and Chicago. The radio stations used in this new service were designed and equipped by Mr. **E. J. Simon.** [2357]

NEW RADIO CALL LETTERS.—Owing to insufficient call letters having been reserved for Japan, the General Administration of Posts and Telegraphs of Japan will assign to Japanese ships call letters composed of four letters by means of the letter **A** at the end of the combinations of three letters commencing with **J.**

The call letters **OKA** to **OKZ** have been reserved for the Republic of Czecho-Slovakia. [2374]

WIRELESS TELEPHONE NEWS SERVICES.—In reply to a recent question in the House of Commons the P.M.G. stated that experiments had been made to distribute news messages by means of wireless telephony from a central station. So far as audibility of the speech was concerned the experiments were satisfactory, but the rate of transmission was slow due to the necessity for frequent repetitions. The news agency on whose behalf the experiments were made has not adopted the system. It was also found that the experiments caused interference with other stations and the trials have been suspended for the present. [2054]

FRANCE: WIRELESS COMMUNICATION WITH BULGARIA.—Wireless communication between Bulgaria and France has been established for private and Press correspondence. The fees are the same as those levied on ordinary lines, the messages bearing the words " non taxee : voie T.S.F." In case of overburdening or interruption of the wireless route, the offices concerned reserve the right of making use of the ordinary telegraph lines. [2042]

Commercial.

COMPAGNIE GÉNÉRALE DE TÉLÉGRAPHIE SANS FIL.—On December 3rd last it was decided to increase the capital of this company by 25 million francs, by the creation of 50,000 new shares of 500 francs each. [2121]

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A NEW RADIO COMPANY.—On March 8th, C. F. Elwell, Ltd., was incorporated as a private limited company with a capital of £50,000. Some of the principal objects of the company are stated to be the development and working of inventions connected with radiotelegraphy and telephony and other methods of intercommunication, and the supply, working and maintenance of masts, arcs, machines, and other apparatus for use in connection with such methods of communication. The first directors are Messrs. J. H. Scrutton (*Chairman*), B. Binyon, C. F. Elwell, and B. E. Mittell. [2381]

The Polish Legation at Washington announces the signature of a million dollar contract with the Radio Corporation of America for the construction at Warsaw of the largest radio station in the world. The station is to have twelve 400-foot steel towers and is to be capable of handling 200 words per minute. [2368]

A NEW BELGIAN HIGH-POWER STATION.—The Belgian Government have decided to erect a 1,000-kW station at Temsche near Antwerp to communicate with the Congo and U.S.A. It will have eight towers 250 metres high. [2382]

A NEW WIRELESS STATION FOR SWITZERLAND.—Marconi's Wireless Telegraph Company have been authorised by the Swiss Federal Government to construct a wireless telegraph station for operation over a period of twenty-five years by a Swiss company. The station is to be erected near Berne about 1,000 feet above sea-level and will employ a valve transmitter of 25 kW capacity; the aerial being carried on two towers each 300 feet high. Up-to-date apparatus for high-speed automatic working will also be employed. The new station will be ready for use by journalists attending the second session of the Assembly of the League of Nations in September next. [2372]

The Australian Government is sending a party of experts to the Willis Islands, with a view to reporting on the possibility of establishing a wireless station there. It is thought that such a station would be of great service to the Commonwealth meteorological service.—*The North Queensland Register.* [2367]

WIRELESS ON ITALIAN VESSELS.—It has been announced that a decree has been published under date of December 27th last to the effect that all Italian motor and sailing vessels of over 1,600 tons and carrying passengers are to be equipped with wireless installations. [2371]

COMMERCIAL WIRELESS IN ITALY.—The use of radiotelegraphy for commercial purposes appears to be making good progress in Italy. Communication has been established with Germany, the United Kingdom, Spain, Switzerland, Rumania, Bulgaria and Serbia, and arrangements are in progress to link up with Hungary, Greece, Portugal, Czecho-Slovakia and Russia. The traffic between ships and coastal stations exceeded 500,000 words last year as compared with 80,000 words prior to the war. The stations on board ship have risen from fifty to more than 300. Two radiotelegraph stations will shortly be established between Sardinia and the Continent to obviate the inconvenience of possible interruptions of the cables. There is the possibility of an Italian company being formed to secure a concession for a group of stations to be used solely in the interest of the public service and of the national and international Press. The Marconi Company has already filed a petition for a concession, which will be examined by the permanent Board for Radiotelegraphic Service. [2382]

The Radio Research Board (Department of Scientific and Industrial Research) have been advertising for research workers of high academic qualifications. Applications should be addressed to the Secretary at 16 and 18, Old Queen Street, S.W. 1. [2211]

WIRELESS AND LONGITUDE.—To determine the exact position of the boundary between South and West Australia it is proposed to utilise wireless telegraphy. To ascertain the exact position of the longitude the use of time signals will be employed from a high power station situated at some point between the Greenwich Observatory in England and Sydney in Australia, the signals being received simultaneously at both places. [2056]

WIRELESS DEVELOPMENT IN AUSTRALIA.—Arrangements are being made for the establishment of wireless stations at Camoweal near the Queensland border, and Powell's Creek, in the Northern Territory. The initial cost will be in the vicinity of £4,000. It is also hoped that private persons will be encouraged to adopt wireless means of communication and that these two stations will act as collecting offices or exchanges for the private plants through

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which business will be conducted with the outer world. A special message fee will be charged for all such private messages. [2375]

WIRELESS TELEGRAPHY AND RAILWAY COMMUNICATION.—Experiments with wireless telegraphy as an auxiliary means of communication on railways have been conducted by the Marconi Co. between Euston and Crewe, and as soon as the Post Office grants a licence, extended trials will be made under commercial conditions. [2043]

JAPAN: NEW WIRELESS STATION.—The wireless station at Tomioka was opened on January 11th. It is the most powerful station in the Orient and is receiving messages direct from New York and other big world stations. Experiments in sending messages have proved very successful, and the station will commence about February 1st. [1997]

WIRELESS TELEPHONE ON LIGHTSHIP.—The installation of the wireless telephone on the Bar Lightship at Liverpool is stated to be the first of the kind for which a licence has been issued. It is intended to provide communication between the lightship and the Dock Board offices and a successful trial took place recently. To prevent interference with marine wireless traffic it has been necessary for the lightship set to be operated on a short wavelength. [2200]

NEW WIRELESS STATION FOR ARGENTINA.—The Argentina Government has granted a concession to the Cie. Générale de Télégraphie sans fil of Paris to construct a wireless station on the Argentina coast for direct radiotelegraphic and telephonic communication with France and other European countries. The duration of the concession is for thirty years. The station is to contain three sets of plant and will be of 800 kW capacity. [2397]

Recent announcements indicate that very good results have been obtained with the radio-telephone station fitted up for experimental purposes by the Westinghouse Electric and Manufacturing Co., Pittsburgh, U.S.A., ranges up to 1,600 miles having been obtained. A recent innovation has been the transmission from this station of the musical services from a local church. [2167]

Legal.

On March 3rd, an important judgment concerning radiotelegraphic work in this country was delivered by Mr. Justice Sargent in connection with the application for the prolongation of the Poulsen Arc patent (No. 15599/1903) which was made by Mr. Christopher Hage, The British and Overseas Engineering Syndicate, Ltd., and the Poulsen Wireless Telegraph Co., Ltd. This patent expired on July 14th, 1917, and the application for extension was lodged on July 5th, 1920. The early history of the patent in question as disclosed in the course of the evidence is extremely complicated, and indicates the difficulty of developing the commercial use of such an invention. Prior to the outbreak of war, the above-mentioned Christopher Hage had secured the sole rights of the patent. After the outbreak of war, the British and Overseas Engineering Syndicate (one of the applicants) was formed. The English patents and some of the foreign ones were sold to this syndicate, which entered into some onerous obligations with the Poulsen Company. By a deed of covenant between the Poulsen Company and the Marconi Company, the latter undertook to fulfil the obligations of the syndicate as regards the provision of capital, etc. Amongst the causes of loss cited by the applicants in connection with the application for the extension of the patent was that owing to the Treasury restrictions it was not possible to call on the necessary capital for the adequate development of the patent, but Mr. Justice Sargent pointed out that the applicants were in fact able to call on the requisite capital by virtue of the agreement with the Marconi Company. He further stated that he did not think that any substantial *prima facie* case had been made out by the applicants for saying that they have had a smaller user of their patents than they would have had if the war had not broken out; and that in his judgment, and having regard to the very strong case which has to be made by any patentee coming so long after the expiration of the patent, this is not a case in which the applicants have made a sufficiently *prima facie* case for it to be necessary to call on the Crown and on the opponents of the applicants. An extension of the patent at the present time could not be in force for more than fifteen months, and would be a hardship to others (notably the Post Office, and Mr. C. F. Elwell who has carried out considerable development work on the system) who had worked the system in the meantime on the understanding that the patent had expired.

The application was therefore dismissed with costs as towards the opponents. [2399]

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Review of Radio Literature.

1. Abstracts of Articles and Patents.

Radio Stations and Installations (General and Descriptive Articles).

1633. **J. Komatsu.** The Choshi Radio Station. (*Pacific Radio News*, 1, pp. 259—261, February, 1920.)
An illustrated description.

1634. **G. M. Claus.** Soesterberg Wireless Station. (*Radio Nieuws*, 3, pp. 283—289, October, 1920.)
An illustrated description of this Dutch station.

1635. **J. C. N. Graafland.** The Lyons Wireless Station. (*Radio Nieuws*, 3, pp. 251—258, September, 1920.)

1636. **B. C. van der Nat.** Wireless Telephone Apparatus. (*Radio Nieuws*, 3, pp. 272—274, September, 1920.)

1637. **J. Corver.** Nauen. (*Radio Nieuws*, 3, pp. 319—324, November, 1920.)
An illustrated descriptive article.

1638. **Van Romunde.** Eighty Kilometre Radio-telephone Set of the S.F.R. (*Radio Nieuws* p. 363, December, 1920.)
A description of a set recently put on the market by the **Société Française Radio-Électrique.** A diagram of connections is given.

1639. **A. Bidault des Chaumes.** The Proposed Radio Station at Sainte-Assise, near Melun (*Génie Civil*, 78, pp. 73—78, January 22nd, 1921.)
A general description of the proposed station,* including a comparison between high-frequency alternators and arcs (see pp. 199—201 in this issue). A description is also given of the high-frequency machines manufactured by the Société Française Radioélectrique, together with the method of joining up two machines in parallel for transmission on the same aerial.

Transmitter Control or Modulation.

1640. **A. S. Blatterman.** The Effect of Modulation Waveshape upon Received Signals. (See RADIO REVIEW, pp. 187-196 in this issue.)

1641. **A. N. Goldsmith.** Controlling the Amplitude of Radio Frequency Continuous Oscillations. (*Wireless Age*, 7, pp. 20—21, June, 1920. *Technical Review*, 6, p. 725, August 31st, 1920—Abstract.)
In the arrangement described both the grid and plate circuits of the oscillating valve or valves form a part of the aerial circuit and in order that the audio frequency control may be more effective a low frequency reaction coupling is provided between the grid and plate circuits so that the modulation current first impressed upon the grid is magnified by the same valves used as low frequency amplifiers.

1642. **Société Française Radio-Électrique.** Wireless Telephony. (*French Patent* 503076, October 26th, 1916. Published June 2nd, 1920. *British Patent* 148955, July 10th, 1920. Convention date October 26th, 1920. Patent not yet accepted but open to inspection.)
The specification describes methods of modulating the exciting current of high-frequency alternators by means of a microphone.

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* See pp. 125—133 in the March, 1921, issue.

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1643. **Cie. Française pour l'Exploitation des procédés Thomson-Houston.** Continuous Wave Transmitter. (*French Patent* 501320, May 10th, 1919. Published April 9th, 1920.)

The specification describes a transmitting apparatus employing modulated continuous waves in which the aerial is tuned to a frequency equal to the sum or difference of the wave frequency and the modulated or amplitude pulsation frequency, and the circuit of the source of oscillations is tuned to the wave frequency or the frequency of the source with the object of keeping the current supplied by the source in phase with the electromotive force.*

1644. **Société Française Radio-Électrique.** Condenser. (*French Patent* 503003, August 28th, 1916. Published June 1st, 1920.)

The specification describes a variable capacity condenser for microphonic currents in which the variation of the capacity is a function of a current in a telephone line. The variation in capacity of the condenser is brought about by vibrating discs of separate telephone receivers on which the magnetic fields of the receiver magnets act.

1645. **Le Matériel Téléphonique.** Continuous Wave Transmitter. (*French Patent* 505106, September 6th, 1918. Published July 23rd, 1920.)

The system is one in which a high-frequency generator is employed and a number of generators of lower frequency are connected through thermionic modulators to tuned circuits coupled with the circuit containing the high-frequency generator.

See also *British Patent* 132562—RADIO REVIEW Abstract No. 224, March, 1920.

1646. **Compagnie Française pour l'Exploitation des procédés Thomson-Houston.** Wireless Telephone Apparatus. (*French Patent* 505956, November 12th, 1919. Published August 11th, 1920. *L'Électricien*, 52, p. 21, January 1st, 1921—Abstract.)

For wireless telephony the vacuum tube is provided with two independent grids, one of which is connected in the high-frequency circuits and the other to a circuit carrying currents of audible frequency, such as a microphone circuit. The transmitting aerial is coupled to the plate-filament circuit and the circuit of the main grid and filament includes an inductance. The main grid is coupled to the plate by a variable condenser. The circuit of the auxiliary grid and filament is connected by a transformer to a microphone circuit. For further particulars see *British Patent* 110924.

1647. **E. W. Scripture.** Nature of Vowel Sounds. (*Nature*, 106, pp. 632—634, January 13th, 1921.)

An oscillographic investigation of speech waveforms, with estimates of the amplitudes of the harmonics therein.

Radio Receiving Apparatus.

1648. Time Signal Receiver Manufactured by the International Radio Company. (*Everyday Engineering Magazine*, 9, p. 250, June, 1920.)

1649. A Portable Receiver. (*Everyday Engineering Magazine*, 9, p. 352, July, 1920.)

A short illustrated description of a set manufactured by the **Esbro Company.**

1650. The Uni-control Receiver. (*Everyday Engineering Magazine*, 9, pp. 650—651, August, 1920.)

An illustrated description of a receiver manufactured by the **Wireless Improvement Company** in which all the adjustments are effected simultaneously by one control handle.

1651. **Gesellschaft für drahtlose Telegraphie, Berlin.** Continuous Tuning for Wireless Telegraphy. (*German Patent* 317543, March 7th, 1917. Patent granted December 24th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 384—385, November, 1920.)

A scheme for tuning an antenna system through a very large scale of wavelengths by means of several variable condenser systems and variometers geared together.

1652. **F. M. Clement.** Design of a Radio Receiving Set. (*Radio News*, 2, pp. 10—11, July, 1920; pp. 76—77, August, 1920.)

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* See also *British Patent* 130369—RADIO REVIEW Abstract No. 123, January, 1920.

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1653. **M. B. Sleeper.** Some Ideals for a Crystal Receiver. (*Everyday Engineering Magazine*, 9, pp. 58—60, April, 1920.)
An illustrated article giving constructional details.

1654. **T. Harvey.** Detector. (*French Patent* 503972, December 18th, 1917. Published June 22nd, 1920. *British Patent* 126381, January 22nd, 1917.)
The invention consists of a mercury coherer for use in wireless telegraphy or cable code telegraphy employing alternating current or interrupted direct current. It consists of one or more globules of mercury placed between two electrodes in a rotating chamber or between two rotating electrodes.

1655. **A. Bonnefont.** Crystal Detector. (*French Patent* 506003, November 13th, 1919. Published August 12th, 1920.)
The device described in the specification comprises a stand carrying a terminal and a milled head which is easily turned by hand. The milled head controls in the interior of the stand a mechanism consisting of one or more movable parts which effect a movement, that is an advance, recession or rotation, to permit a suitable point to explore the crystal carried in the interior of the stand so as to find the most sensitive points of the said crystal.

1656. **H. Rehmann.** Contact E.M.F. and Rectification. (*Physikalische Zeitschrift*, 21, pp. 699—703, December 1st, 1920.)
Experimental investigation of fine micrometer contact phenomena between polished metal surfaces, leading the author to the conclusion that there are two badly conducting layers, the inner one giving the microphone effects and the outer the voltaic contact E.M.F. A platinum and silver contact the moisture of which contains a minute amount of iodine gave a very effective rectification, the resistance in one direction being more than 10^6 times that in the other. See also Abstract No. 1240, December, 1920, for reference to earlier experiments.

1657. **W. W. Inder.** Balanced Crystal Working. (*The Radiograph*, 2, pp. 10—12, July, 1920.)

1658. A Long Wave Receiver. (*Everyday Engineering Magazine*, 9, pp. 63—65, April, 1920.)
An illustrated description of the C.R.-7 set manufactured by the **A. H. Grebe Company.**

1659. **L. M. Clemont.** The Problems of Vacuum Tube Circuits: Detection with a Grid Condenser. (*Everyday Engineering Magazine*, 9, pp. 66—67, April, 1920.)

1660. **M. B. Sleeper.** Construction of a Portable Receiver. (*Everyday Engineering Magazine*, 8, pp. 408—411, March, 1920.)
An illustrated descriptive article of a single valve receiver for tuning between 200 and 2,000 metres wavelength.

1661. **S. D. Dimond and J. A. Hall.** Equipment for the Radio Station. (*Everyday Engineering Magazine*, 9, pp. 442—444, August, 1920.)
A valve receiver and 200 metre rotary spark transmitter are described and illustrated.

1662. **M. B. Sleeper.** A Short Wave Regenerative Receiver. (*Everyday Engineering Magazine*, 9, pp. 538—539, September, 1920.)
Constructional details are given for a single valve receiver for tuning between 150 and 600 metres.

1663. Detector and Amplifier Units. (*Everyday Engineering Magazine*, 9, p. 549, September, 1920.)
A short illustrated description of two units manufactured by the **Clapp-Eastham Company.**

1664. **M. Latour.** Relay. (*French Patent* 502476, September 27th, 1915. Published May 15th, 1920. *British Patent* 153319, July 12th, 1920. Convention date, September 27th, 1915. Patent not yet accepted but open to inspection.)
The specification relates to thermionic relays in which an alternating current is directly applied to the anode circuits of the receiving or amplifying valves. To eliminate the effects of this alternating supply voltage, two valves are used, fed from the same source through the primary windings of two transformers, the secondary windings of which are connected in opposition on the output circuit of the amplifier, so that the impulses of plate current through the two primaries cancel out. The input circuit is connected to the two grid circuits of the

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valves, so that the potential of one valve is raised when the other is lowered. This causes an unbalancing of the two plate currents, with the result that the two E.M.F.s in the output circuit no longer cancel. By inserting a detector in the output circuit the device may be employed for continuous wave reception, the low frequency supply to the anodes acting as a tikker.

1665. **E. F. Huth.** Circuit for Wireless Transmission and Reception. (*German Patent* 310774, October 5th, 1918. Patent granted October 1st, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 432, May, 1920—Abstract.)

A triode transmitter and receiver (see Fig. 1) in which one pole of the high tension battery is connected to the filament and the other through a large choking coil C to the grid condenser. The telephone T and blocking condenser B are cut out during transmission.

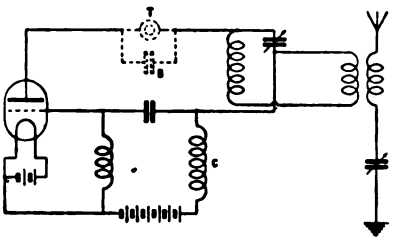

FIG. 1.

1666. **Société Française pour l'Exploitation des procédés Thomson-Houston.** Receiving Apparatus. (*French Patent* 504250, September 26th, 1919. Published June 28th, 1920. *L'Électricien*, 51, p. 547, December 15th, 1920—Abstract.)

Means are provided in a wireless receiving system employing an electron discharge amplifier having resonant grid and plate circuits, for preventing the generation at all frequencies of oscillations due to the electrostatic and electromagnetic coupling between the grid and plate circuits. To prevent electromagnetic coupling of the resonant grid and plate circuits the inductances of these circuits are enclosed in metal boxes or are provided with closed iron cores. For further particulars, see *Britisb Patent* 119365.

1667. **H. C. Harrold.** Thermionic Valves and their Application to Wireless Telegraphy. (*The Radiograph*, 2, pp. 72—74, September, 1920; pp. 95—97, October, 1920; pp. 121—123, November, 1920.)

1668. **P. F. Godley.** High Amplification of Short Wavelengths. (*Wireless Age*, 7, pp. 11—14, February, 1920. *Q.S.T.*, 3, pp. 5—9, February, 1920. *Electrical World*, 75, p. 1015—Abstract.) Also **P. R. Coursey.** The Most Efficient Methods of Reception of Short Waves both Spark and C.W. (*Wireless World*, 8, pp. 581—583, November 13th, 1920.) Also **H. W. Houck.** The Armstrong Super-autodyne Amplifiers. (*Radio Amateur News*, 1, pp. 403—405, February, 1920; pp. 469—471, March, 1920. *Radioélectricité*, 1, p. 70, June, 1920—Abstract.)

A description is given of a special amplifier for short wavelengths due to **E. H. Armstrong.** Circuit diagrams of the arrangements for open aerials and for loop aerials are given and constructional details are described for building the instruments. The principle of the arrangement is covered by the patents referred to in RADIO REVIEW Abstracts Nos. 983 and 992, October, 1920.

1669. **Gesellschaft für drahtlose Telegraphie, Berlin.** Continuous Wave Receiver. (*German Patent* 317544, June 26th, 1918. Patent granted December 22nd, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 385, November, 1920—Abstract.)

A heterodyne receiving circuit designed to make the radiation of the locally produced waves a minimum (see Fig. 2).

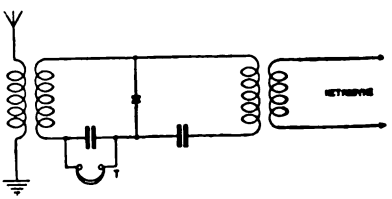

FIG. 2.

1670. **A. S. Blatterman.** Radio Frequency Amplification. (*Radio News*, 2, pp. 140—142, and 166—170, September, 1920.)

A mathematical discussion is given of the method of radio frequency amplifications using

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a supersonic beat frequency.* Formulæ are given to assist in the design of the amplifying transformers and it is concluded that the method should be freer from interference by atmospherics and highly damped spark stations.

1671. **E. H. Shaughnessy.** A New Wireless Call Arrangement. (*Electrical Review*, 87, pp. 68—69, July 16th, 1920. *Post Office Electrical Engineers Journal*, 13, pp. 263—267, January, 1921. *L'Électricité*, 2, p. 5, August 15th, 1920—Abstract. *Nature*, 105, p. 690, July 29th, 1920—Abstract. *Technical Review*, 7, p. 182, November 9th, 1920—Abstract. *Science Abstracts*, 23B, p. 493, Abstract No. 936, October 31st, 1920—Abstract. *Elektrotechnische Zeitschrift*, 41, p. 962, December 2nd, 1920—Abstract.)

A calling arrangement is described for wireless receiving depending for its operation upon the receipt of a prolonged dash of at least 15 seconds duration. In place of the usual telephone receivers a two or three valve note magnifier is arranged to be plugged in when the operator is not on watch. The output of this note magnifier is connected to a Turner valve relay. The output circuit of this relay is connected to the first relay of an electrical retardation device the function of which is to prevent the ringing of the bell for Morse signals or for short dashes or by atmospherics. The receipt of the signal causes the Turner valve relay to operate and thus to move the tongue of the first relay of the retardation device on to the marking contact to close the circuit of a 4 microfarad condenser on to a 12 volt battery through a resistance of 3 megohms which causes the condenser to charge up very slowly. On the cessation of the signal the tongue of this relay moves back and discharges the condenser through the second relay of the retardation device, the local circuit of the second relay including the call bell. Thus if the signal dash lasts for a sufficiently long period a charge will be accumulated in the 4 microfarad condenser of sufficient magnitude to operate the final relay and ring the bell. Reference is also made to some tests of the apparatus on the cable ship *Monarch* and in the Post Office research laboratories.

1672. **A. A. Campbell Swinton.** Wireless Telegraphy and Telephony. (*Engineer*, 130, pp. 592—594, December 10th, 1920.)

A full report is given of the opening address by the Chairman of the Council of the Royal Society of Arts. (See RADIO REVIEW Abstract No. 1386, January, 1921.)

1673. **L. B. Turner.** Relay. (*French Patent* 505712, February 13th, 1919. Published August 5th, 1920.)

The specification describes arrangements employing a thermionic or lamp relay.

See also *British Patent* 130408—RADIO REVIEW Abstract No. 196, February, 1920.

Amplifiers.

1674. **M. B. Sleeper.** A Radio Frequency Amplifier without Transformers. (*Everyday Engineering Magazine*, 8, pp. 414—416, March, 1920.)

Constructional details are given of a two-stage amplifier and detector with tuned circuit inter-valve couplings.

1675. **M. B. Sleeper.** A Two Step Audio Frequency Amplifier. (*Everyday Engineering Magazine*, 9, pp. 344—346, July, 1920.)

An illustrated descriptive article.

1676. **M. B. Sleeper.** Radio and Audio Frequency Amplifier. (*Everyday Engineering Magazine*, 10, pp. 56—58, October, 1920.)

Constructional details of a three-valve amplifier and detector.

1677. **F. Duroquier.** A Resistance Amplifier. (*La Nature*, 48 (2), Supplement pp. 83—85, September 11th, 1920; Supplement pp. 91—93, September 18th, 1920.)

Constructional details are given.

1678. **F. Duroquier.** The Construction of a Low Frequency Transformer Coupled Amplifier. (*La Nature*, 48 (2), Supplement pp. 115—197, October 9th, 1920.)

1679. **A. H. de Voogt.** Marconi's High-frequency Amplifier. (*Radio Nieuws*, 3, pp. 239—243, August, 1920.)

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* See also RADIO REVIEW Abstract No. 1668 in this issue.

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1680. **J. Corver.** Short-wave High Frequency Amplification. (*Radio Nieuws*, 3, pp. 262—265, September, 1920.)

1681. **N. de Voogd.** High-frequency Amplifier. (*Radio Nieuws*, 3, pp. 338—341, November, 1920.)

1682. **Gesellschaft für drahtlose Telegraphie.** Reception of Continuous Waves. (*German Patent* 310733, November 9th, 1918. Patent granted September 20th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 233, September, 1920—Abstract.)

An arrangement of valves in cascade in which one valve acts both as amplifier and heterodyne. (See Fig. 3.)

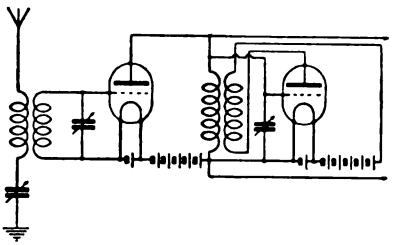

FIG. 3.

1683. **Société Française pour l'Exploitation des procédés Thomson-Houston.** Amplifier. (*French Patent* 499563, May 5th, 1919. Published February 14th, 1920.)

An amplifier for telephone currents.

1684. **Société Française pour l'Exploitation des procédés Thomson-Houston.** Amplifier. (*French Patent* 500618, June 11th, 1919. Published March 18th, 1920.)

This specification describes a method of amplifying telephone currents.

1685. **W. Took.** The Vacuum Tube in France. (*Radio Amateur News*, 1, p. 466, March, 1920.)

A description of French multi-valve amplifiers.

Subsidiary Radio Apparatus.

1686. **M. Gouzon.** A Method of Prolonging the Life of Dry Cells used for High Tension Batteries. (*La Nature*, 48 (2), Supplement p. 117, October 9th, 1920.)

1687. **M. Marage.** The Threshold of Audition. (*Comptes Rendus*, 172, pp. 178—181, January 17th, 1921.)

A consideration of the sensitiveness of the ear to sounds of different types.

1688. **H. W. Secor.** Loud Talking Reproducer for Radio and Telephone Signals. (*Radio News*, 2, p. 211, October, 1920.)

Constructional details are given for an instrument of the electrodynamic type.

1689. Radio Buzzer Instruments. (*Everyday Engineering Magazine*, 8, pp. 417—419, March, 1920.)

Aerials and Earthing Systems.

1690. **J. Bethenod.** Aerial Construction. (*French Patent* 497313, April 20th, 1918. Published December 3rd, 1919.)

The specification describes a system of aerials for the emission of electromagnetic waves of great wavelength and produced by an arc or high frequency alternator, in which two or more aerials are directed orthogonally and are fed with out-of-phase currents. There are no drawings.

1691. **C. L. Allen.** A Simple Ready-made Aerial. (*Wireless Age*, 7, pp. 32—34, March, 1920.)

The use of rain water pipes and gutters as aerials for wireless receiving is described.

1692. **F. C. Brockman.** The Construction of a Portable Antenna. (*Wireless Age*, 7, pp. 30—31, September, 1920.)

1693. **A. H. Rice.** The Construction of a Portable Antenna. (*Wireless Age*, 7, pp. 31—34. September, 1920.)

1694. **P. H. Boucheron.** Concerning Aerials. (*Radio News*, 2, pp. 18—20, July, 1920.)

A general descriptive article.

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1695. **M. B. Sleeper.** The Design and Use of Loop Antennas. (*Everyday Engineering Magazine*, 9, pp. 440—441, August, 1920.)

1696. **S. E. Moore.** The Tree Antenna. (*Radio Amateur News*, 1, p. 484, March, 1920.)

1697. **P. Dosne.** A Table Antenna. (*La Nature*, 48 (2), pp. 302—304, November 6th, 1920.)

The author describes the use of a frame aerial in a horizontal position for general reception purposes, the receiving instruments being mounted in the centre of the frame. The use of a telegraphone for recording purposes is also referred to.

1698. **A. Esau.** Frame Antennæ. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 486, June, 1920. Abstracted from *Elektrotechnik und Machinenbau*, 37, p. 401, 1919.)

1699. **A. Gradenwitz.** Braun Loop Antenna. (*Radio News*, 2, pp. 70 and 100, August, 1920.)

A general account of the development of frame aerials.

1700. **A. A. Hall.** Aerial Construction. (*French Patent* 505678, November 4th, 1919. Published August 4th, 1920. *British Patent* 142886, November 18th, 1918. Patent accepted May 18th, 1920.)

The usual aerials are not employed. The receiving and transmitting stations have a double earth connection spaced apart by a considerable distance. The connections to the earth are made by insulated conductors lying on the ground. The two earth connections are included in the anode circuit of either the transmitting or receiving valve, a reaction coil being provided for coupling to the grid circuit to enable the circuits to generate oscillations. For transmission a key is placed in one of the earth connections.

1701. Condenser Antennæ. (*Telegraph and Telephone Age*, 38, p. 650, December 16th, 1920.)

Describes briefly experiments carried out by the **Bureau of Standards** on aerials consisting of a pair of metal plates, the lower one of which is raised above the ground. For short wavelengths it is stated that these aerials give better signals than the more conventional forms.

1702. Submarine Radio. (*Telegraph and Telephone Age*, 38, p. 650, December 16th, 1920.)

A short note on experiments on communication with submerged submarines.

1703. **A. S. Blatterman.** Theory and Practical Attainments in the Design and Use of Radio Direction Finding Apparatus using Closed Coil Antennas. (*Journal of the Franklin Institute*, 190, p. 421, September, 1920. *Science Abstracts*, 23B, p. 546, Abstract No. 1036, November 30th, 1920—Abstract. *Technical Review*, 7, p. 428, December 28th, 1920—Abstract.)

A supplementary note extending the data given by the author in an earlier paper.* Test results are quoted for 4-foot and 6-foot loops having $\frac{1}{4}$-inch and $\frac{7}{16}$-inch wire spacing respectively. Three tables are given of the measured resistances at different wavelengths.

1704. **A. Esau.** Coil Aerials: their Inductance, Capacity and Natural Frequencies. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 162—199, September, 1920.)

Gives formulæ for the calculation of the inductance of rectangular and circular coils, the effect of unequal distribution of the current at high frequencies, both over the cross-section of the wire and along the coil, and the self-capacity of such coils. In all cases a number of measured values are given, showing the agreement with or deviation from the calculated values.

1705. **A. F. Murray.** A Loop Transmitter for Local Work. (*Wireless Age*, 7, pp. 25 and 41, July, 1920.)

Particulars are given of an installation using an elevated antenna for long distance work and a loop aerial for short distance transmission, the same equipment being transferred from one to the other with appropriate switches.

1706. **L. D. Dillenback.** A 100 Foot Radio Mast. (*Wireless Age*, 7, pp. 28—29, April, 1920.)

The mast described is built up of sections of iron piping screwed together.

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* See RADIO REVIEW Abstract No. 144, January, 1920.

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1707. **F. H. Mulcahy.** An Easily Constructed Mast. (*Wireless Age*, 7, pp. 30—32, April, 1920.)
Constructional details are given.

Radio Wave Transmission (Theory, Tests, etc.).

1708. **G. W. O. Howe.** The Power required for Long Distance Wireless Transmission. (*Science Abstracts*, 23B, p. 543, Abstract No. 1029, November 30th, 1920—Abstract.)
RADIO REVIEW, 1, pp. 598—608, September, 1920.

1709. **P. Ludewig.** The Influence of Meteorological Factors on Wireless Telegraphy. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 479—480, June, 1920. Abstracted from *Elektrotechnik und Machinenbau*, 32, pp. 181—209, 1914.)

1710. **C. E. Snell.** The Function of the Earth in the Transmission of Electricity. (*Electrical Review*, 87, pp. 421—423, October 1st, 1920.)
Brief summaries are given of the various viewpoints from which the subjects of electrical current transmission through the earth and of electromagnetic wave transmission over the earth's surface have been attacked. Some experiments are quoted bearing on the subject of transmission of high frequency impulses along conductors from which it is concluded that for the transmission of electric waves over considerable distances the most efficient method is to connect the two points by a conductor of limited dimensions, and that this conductor must not make contact *en route* with any considerable mass of conductive material.

1711. **G. W. O. Howe.** Field Strength at Leghorn of Annapolis Signals. (*Technical Review*, 7, p. 391, December 21st, 1920—Abstract.)
RADIO REVIEW, 1, pp. 652—655, October, 1920.

1712. **G. Vogt.** The Reception of Wireless Signals in the East Indies. (*Radio Nieuws*, 3, pp. 291—294, October, 1920.)

1713. Wireless Telephony. (*Electrical Review*, 87, p. 146, July 30th, 1920.)
Reference is made to long distance wireless telephone communication with the S.S. *Victorian*.

1714. Wireless Telephony. (*Electrical Review*, 87, p. 627, November 12th, 1920.)
Refers to tests between Keyport (N.J.), U.S.A., and Aberdeenshire, Scotland, carried out by amateurs.

1715. **M. Sauzin.** On the Propagation of Undamped Electric Oscillations in Water and on the Dielectric Constant of Water. (*Comptes Rendus*, 171, pp. 164—167, July 19th, 1920. *Revue Scientifique*, 58, p. 473, August 14th, 1920—Abstract.)
Experiments are described using ultra-radio frequency oscillations from a valve generator, and stationary waves on parallel wires, which could be immersed in water for part of their length. Using wavelengths of 445 cms and 242 cms, the mean dielectric constant was found to be 73 for distilled water, and 75 for tap water (at Nancy).

Atmospherics and Anti-Atmospheric Devices.

1716. Forecasting Weather from Static. (*Radio Amateur News*, 1, p. 465, March, 1920.)

1717. **H. J. J. M. de R. de Bellescize.** Eliminating Atmospheric Disturbances. (*French Patent* 504782, October 10th, 1919. Published July 6th, 1920.)
For the reception of wireless telegraphy or wireless telephony a closed damping circuit is provided comprising an inductance in series with two resistances of considerably different values, and the two resistances and the inductance are shunted by a rectifying contact. The damping circuit is coupled to a feebly-damped resonator and by it parasitic currents are eliminated.

1718. A New Static Eliminator. (*Radio News*, 2, p. 71, August, 1920.)
An acoustic resonance method is described.

1719. **W. Gerlach.** On a Method of Reducing the Effect of Atmospherics. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 337—344, November, 1920.)
After a brief discussion of the different schemes which have been proposed to eliminate atmospheric interference the author describes experiments illustrating the difference between two types of atmospheric disturbance. The same atmospherics were registered by means

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of a crystal and galvanometer, by telephone and also by means of a thermo-element and accessory galvanometer. Atmospherics of the strong type which last only a short time were registered by the crystal and galvanometer but not to any great extent by the thermo-couple. Weaker atmospherics of the growling type which are supposed to be of fairly long duration produced much bigger deflections on the thermo-couple galvanometer.

A method of reducing the effect of an atmospheric is suggested in which a conductor or cell of special type is used as a connection between a point on the aerial tuning inductance and earth. This conductor or cell must be such that its conductivity does not become appreciable until a certain potential difference is maintained between its ends (*e.g.*, carborundum). Experiments were made on a large antenna at Jena to test the efficacy of this method. Curves are given showing the relation between the ratio of the atmospheric effect before and after making the parallel connection mentioned and the particular points on the antenna inductance at which the connection was made.

Duplex Radio Communication.

1720. **Société Française pour l'Exploitation des procédés Thomson-Houston.** Duplex Working. (*French Patent* 503827, September 12th, 1919. Published June 18th, 1920. *British Patent* 150798, June 5th. Patent accepted September 6th, 1920.)

In a receiving system adapted for duplex telegraphy or telephony the receiving coil is in two halves having large mutual inductance and the junction point is earthed so as to provide a non-inductive path to earth for currents induced electrostatically by a neighbouring transmitting aerial.

1721. **H. J. J. M. de R. de Bellescize.** Duplex Wireless Systems. (*French Patent* 506141, January 22nd, 1919. Published August 14th, 1920.)

In duplex wireless systems in which there is a transmitting station having associated with it one or more receiving stations, the signals are received by the operator at the transmitting station by being transmitted thereto over telephone lines connected to the receiving circuits.

See also *British Patent* 134497, RADIO REVIEW Abstract No. 906, October, 1920.

High-frequency Circuits and Measurements (Theory, Components, etc.).

1722. **P. Boucherot.** A New Method of Calculation by the Separation of Power Applicable to Radiotelegraphy. (*Radioélectricité*, 1, pp. 73—81, July, 1920. *La T.S.F. Moderne*, 1, pp. 283—285, November, 1920—Abstract.)

The author suggests a simplification of the calculations necessary in connection with C.W. transmitting apparatus, by the application of the simple formulæ of ordinary alternating-current electrical engineering. The use of instantaneous values is dispensed with in favour of the use of expressions for "real" and "apparent" power of the type $IV\cos\phi$ and $IV\sin\phi$.

1723. **H. G. Cordes.** The Theory of Linear-sinoidal Oscillations. (*Physical Review*, 16, pp. 179—201, September, 1920. *Science Abstracts*, 23A, pp. 656—657, Abstract No. 1645, December 30th, 1920—Abstract.)

When a vacuum arc is shunted with a discharge circuit containing inductance, capacity and resistance, and is supplied with direct current through a large inductance the arc vapour is ionised and de-ionised periodically at a constant frequency. The author terms the variation of potentials and current in a discharge circuit "linear-sinoidal oscillations" and mathematical expressions are derived for their logarithmic decrement, frequency and other quantities. The relation between the values of the direct current supply and the effective currents through the arc and in the discharge circuit is established. It is also shown that the value of the series resistance required to produce stability depends upon the discharge circuit resistances and on the rate of de-ionisation of the vapour. Auxiliary means are required to stabilise the oscillations if required for radio signalling.

1724. **K. W. Wagner.** The Penetration of an Electromagnetic Wave into a Coil having Self-capacity. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 484, June, 1920. Abstracted from *Elektrotechnik und Machinenbau*, 33, pp. 89—105, 1915.)

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1725. **K. Zickler.** The Calculation of the Alternating-current Resistance of Iron Conductors of Circular Cross-section. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 486—487, June, 1920. Abstracted from *Elektrotechnik und Machinenbau*, 37, p. 449, 1919.)

1726. **J. Bethenod.** On the Influence of Antenna Height on the Range of Wireless Stations. (*Radioélectricité*, 1, p. 285, November, 1920.)

Assuming uniform electrical strain on the insulators supporting the antenna, and that the whole effective capacity of the aerial is concentrated in the upper flat part, it is shown that the dependence of the received signal strength on the height of the transmitting aerial is given by a factor $m = 1 + 2{\cdot}55H/R$ where H = height and R = effective radius of the upper flat part of the aerial. An increase of the height of an aerial from 100 to 200 metres would thus result in an increase of 33 per cent. only in the received signal strength.

Simple relations are also suggested for quickly determining the most economical height of the towers from the point of view of their cost.

1727. **P. R. Coursey.** Multi-layer Windings for Radio Receiving. (*Wireless World*, 8, pp. 473—476, October 2nd, 1920; pp. 505—508, October 16th, 1920; and pp. 539—541, October 30th, 1920. *Technical Review*, 7, p. 222, November 16th, 1920—Abstract.) Also Lattice-wound Coils. (*Wireless World*, 8, pp. 635—637, December 11th, 1920.)

Describes the various forms of multi-layer windings including the honeycomb and duolateral with similar modifications. Winding tables are also given.*

1728. Duolateral Type Inductance. (*Everyday Engineering Magazine*, 9, p. 254, June, 1920.)

1729. **K. H. Stark.** A New Development in Tuning Inductances. (*Everyday Engineering Magazine*, 9, pp. 446—447, August, 1920.)

An illustrated description of a multi-layer inductance winding for radio frequency consisting of a combination of lattice winding and ordinary spiral winding used in alternate layers.†

1730. Precision Radio Measurements. (*Everyday Engineering Magazine*, 9, pp. 542—543, September, 1920.)

A short illustrated description of a wavemeter, a variable condenser and a variable inductance manufactured by the **General Radio Company.**

1731. Variometer or Coupling Coils. (*Everyday Engineering Magazine*, 9, pp. 546—547, September, 1920.)

Constructional details are given.

1732. Variometer. (*Electrical World*, 76, p. 905, October 30th, 1920.)

A short note illustrating the variometer type Z.R.V. manufactured by the **Clapp-Eastham Company.**

1733. **J. Philips.** The New Inductance Coils. (*Radio Nieuws*, 3, pp. 244—245, August, 1920.)

A brief description of lattice windings.

1734. **Gesellschaft für drahtlose Telegraphie, Berlin.** Self-inductance for Wireless Telegraphy. (*German Patent* 309211, June 19th, 1918. Patent granted September 22nd, 1919 *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 235, September, 1920—Abstract.)

A coil (see Fig. 4) for use in valve work which has no external electromagnetic effect and so does not give rise to undesirable coupling.

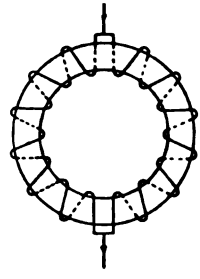

FIG. 4.

1735. **H. C. Silent.** Banked Winding. (*Radio Amateur News*, 1, p. 411, February, 1920.)

1736. **O. C. Roos.** Anti-capacity Windings *versus* Coil Efficiency. (*Radio News*, 2, p. 85, August, 1920.)

The author concludes that a graded coil as regards size and separation of wires and pitch would improve the efficiency. The development of multi-layer windings is also traced.

* See also RADIO REVIEW Abstract No. 1413, January, 1921.

† This winding is also described in the article referred to in Abstract No. 1727 above.

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1737. **P. F. Geagan.** Inductances that Fit. (*Experimental Science*, 1, pp. 54—55, August, 1920.)

Deals with the design of transmitting inductances for 200-metre wavelengths.

1738. **A. Tobler.** The Use of a Valve Oscillator for the Measurement of Inductance and Capacity at the General Post Office, London. (*Journal Télégraphique*, 44, pp. 189—190, December 25th, 1920.)

A correction to the article referred to in Abstract No. 1496, February, 1921.

1739. **B. Ames.** Condenser. (*French Patent* 501024, June 24th, 1920. Published March 31st, 1920. *British Patent* 137003, May 29th, 1919.)

The specification describes a condenser of the type having alternate sheets of conducting and insulating material and in which alternate conducting sheets project in two different directions from the edges of the insulating sheets.

1740. **L. B. Turner.** Everyday Measurement of Inductance and Capacity in the Wireless Laboratory. (*Technical Review*, 7, p. 323, December 7th, 1920—Abstract. *Science Abstracts*, 23B, p. 515, Abstract No. 985, November 30th, 1920—Abstract.)

See RADIO REVIEW, 1, pp. 585—590, September, 1920.

1741. **L. M. Clemont.** The Measurement of High Frequency Resistance. (*Everyday Engineering Magazine*, 9, pp. 252—253, June, 1920.)

Description of various arrangements of bridge and other high-frequency resistance measuring circuits.

1742. **V. L. Freeman.** A Simple Method of Measuring Inductances at Low Frequencies. (*Everyday Engineering Magazine*, 9, pp. 354—355, July, 1920.)

1743. **G. Pession.** Capacity of Aerials. (*L'Elettrotecnica*, 8, pp. 10—13, January, 1921. See also p. 1 in same issue.)

A discussion of the static and dynamic capacities of aerials and the correct meaning to be attached to the latter expression. Accurate measurements on the San Paulo aerial at Rome are recorded, the static capacity was found to be 13 milli-microfarads and the equivalent capacity at the fundamental wavelength of 3,300 metres 11·8 milli-microfarads.

1744. **M. B. Sleeper.** A Heterodyne Wavemeter for 170 to 21,000 Metres. (*Everyday Engineering Magazine*, 9, pp. 247—250, June, 1920.)

An illustrated description with constructional details.

1745. U.S. Bureau of Standards Long Wave Wavemeter. (*Everyday Engineering Magazine*, 10, p. 64, October, 1920.)

An illustrated description.

1746. **H. Veenstra.** Direct Reading Wavemeter. (*Radio Nieuws*, 3, pp. 331—335, November, 1920.)

The arrangement described and illustrated is that referred to in connection with Fig. 3 on p. 721 of the RADIO REVIEW Abstract No. 1056, November, 1920.

1747. **J. S. E. Townsend.** High Frequency Measurements. (*French Patent* 499497, March 2nd, 1918. Published February 12th, 1920.)

The specification describes a variable inductance for use in measuring wavelengths and tuning in wireless telegraphy. It consists of a variometer comprising two coils, one rotatable within the other and a switch for changing the connections from series to parallel. For further particulars see *British Patent* 115876.

1748. **A. V. Bailhatchet.** A Wavemeter. (*Model Engineer*, 44, pp. 89—91, February 3rd, 1921.)

Gives constructional details.

1749. **W. Burstyn.** Measurement of High Frequency Energy. (*German Patent* 300043, November 24th, 1916. Patent granted December 15th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 379—380, November, 1920.)

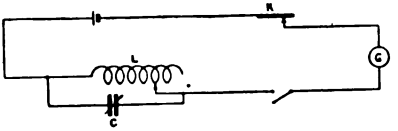

FIG. 5.

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A method of measuring the high frequency energy associated with an oscillating circuit without a spark gap. The direct current circuit (see Fig. 5) is suddenly broken, the energy of the oscillating circuit then being $\frac{1}{2}LJ^2$ where J is the reading of the galvanometer when the key is closed. The time constant of the direct current circuit is made smaller than the time of contact by the insertion of a sufficiently high resistance.

1750. **C. T. R. Wilson.** On a Micro-voltameter. (*Proceedings of the Cambridge Philosophical Society*, 19, p. 345, February, 1920. *Science Abstracts*, 23A, p. 588, Abstract No. 1482, November 30th, 1920.)

An apparatus for the measurement of very minute quantities of electricity.

1751. **R. S. Whipple.** Some Notes on the Electro-cardiograph. (*Journal of the Institution of Electrical Engineers*, 57 Supplement, pp. 13—28, April, 1920. *Science Abstracts*, 23A, p. 660, Abstract No. 1657, December 30th, 1920—Abstract.)

The paper includes some particulars of the various patterns of Einthoven galvanometer manufactured by the Cambridge Scientific Instrument Co. The maximum sensitiveness quoted is 1 mm deflection on the screen at 600 diameters magnification for 0·000015 microamperes.

1752. **J. K. A. W. Salomonson.** The Limit of Sensitiveness of the String Galvanometer. (*Proceedings of the Koninklijke Akademie van Wetenschappen of Amsterdam*, 23, pp. 613—615, No. 4, 1921.)

The continuation of a paper published in 1918 on the sensitiveness of the Einthoven galvanometer. It is shown that the previously obtained results should be modified by the effect of the weight of the string and that when this is done the calculated deflection agrees fairly closely with the observed values.

1753. **W. Einthoven.** On the Observation and Representation of Thin Threads. (*Proceedings of the Koninklijke Akademie van Wetenschappen of Amsterdam*, 23, pp. 705—706, No. 5, 1921.)

Discusses the observation of very thin threads for Einthoven galvanometers and the limitations of their magnifications by means of a microscope.

1754. **B. van der Pol.** Discontinuities in the Magnetisation. (*Proceedings of the Koninklijke Akademie van Wetenschappen of Amsterdam*, 23, pp. 637—643, No. 4, 1921.)

The use of an amplifier is described for investigating the sounds occurring when iron is magnetised. The connection with the "breathing" sound of a magnetic detector is pointed out.

2. Books.

A COURSE OF MODERN ANALYSIS. By E. T. Whittaker and G. N. Watson. (London: *Cambridge University Press*. 1920. Pp. xxiii + 608. Price 40s. net.)

The scope of the third edition of this well-known book is indicated by its sub-title, "An Introduction to the General Theory of Infinite Processes and of Analytic Functions; with an Account of the Principal Transcendental Functions." It is divided into two parts dealing respectively with the processes of analysis and the transcendental functions. It differs from the second edition by the addition of a chapter on Ellipsoidal Harmonics and Lamé's Equation, and by the rearrangement of the chapter on Trigonometrical Series so that the parts which are used in applied mathematics come at the beginning of the chapter. A large number of examination questions are given at the close of each chapter, together with a list of references to more specialised works in the subject of the chapter. The large number of references throughout the book greatly add to its value, as do also the tabulated list of the authors quoted and the very complete index. It is essentially a book for the mathematician and makes considerable demands on the reader's mathematical knowledge and power of abstract conception. To a physicist or engineer of modest mathematical attainments Chapter XVIII. on the Equations of Mathematical Physics will appear somewhat of an oasis; but even here a close examination may prove disappointing.

To the student of modern mathematical analysis the book will be indispensable.

G. W. O. H.

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ELEMENTS OF RADIOTELEGRAPHY. By Ellery W. Stone, M.Inst.R.E., Lieutenant, U.S.N.R.F. (New York: *D. van Nostrand Co.* London: *Crosby Lockwood & Son.* 1920. Pp. vii + 267. Price 16*s.* 6*d.* net.)

This book is, in the main, a *résumé* of a series of lectures delivered to the radio classes at the U.S. Naval Radio Station, San Diego, and on this understanding much of the criticism which might be levelled against it falls to the ground. Even the belief of the author that it will be found helpful in radio instruction in other military branches of the Government and in civilian radio schools merits our cheerful acquiescence. But that it possesses any special value for "the self-instruction of those interested in the subject" we must be permitted to doubt, without implying that as a source of information it is indifferent.

Lieutenant Stone's book contains 267 pages, including twelve covered by the Appendix and Index. Within this narrow scope are packed eleven chapters each of which deals with a number of subjects. In Chapter I., five and a half pages are devoted to the principles of radiotelegraphy, three and a half to electrical terms, between three and four pages to condensers, a page to inductances, less than thirty lines to electromagnetic induction and ten pages to alternating current.

One page only is devoted to the Marconi system of transmission, whilst the Telefunken system is dismissed in eleven lines. On the other hand eighteen pages are given up to the Poulsen arc transmitter and eleven pages to decremeters. The text referring to thermionic valves is in the form of brief, condensed notes.

These examples are sufficient to show that for self-instruction the student should look elsewhere.

The only references to direction finding or to the directional properties of certain antennæ occur in the notes on the inverted L and loop types, no mention being made of the Bellini-Tosi aerial. Only two pages are devoted to high-frequency machines, in which no pretence of detailed description is made.

The following might be improved: "A condenser or capacity is made of a piece of dielectric coated on each side with a conductor."

The book is well printed on good paper and the half-tone illustrations are well done.

E. BLAKE.

REPORT OF THE CHIEF SIGNAL OFFICER OF THE U.S. ARMY TO THE SECRETARY OF WAR (U.S.A.) for the year ended June 30th, 1920. (Washington: *Government Printing Office.* 1920. Pp. 64.)

This report is largely concerned with the activities of the Signal Corps in the occupied Rhine territory, especially Coblentz. It contains many interesting details and statistics and is illustrated with photographs showing different branches at work. G. W. O. H.

REPORT OF THE DIRECTOR OF THE AIR SERVICE TO THE SECRETARY OF WAR (U.S.A.) for the year ended June 30th, 1920. (Washington: *Government Printing Office.* 1920. Pp. 49.)

This report deals with the organisation of the Air Force, clearly set out under various headings. Chapter IV. on Air Service Accomplishments, and Chapter V. on Projects and Undertakings are especially interesting. Wireless work is apparently not referred to.

G. W. O. H.

Books Received.

MODERN HIGH-SPEED INFLUENCE MACHINES, their Principles, Construction and Applications to Radiography, Radiotelegraphy, Spark Photography, Electro-Culture, Electro-Therapeutics, High-tension Gas Ignition, the Testing of Materials, etc. V. E. Johnson, M.A. (London: *E. and F. N. Spon, Ltd.* 1921. 8½″ × 5½″. Pp. viii + 278. Price 14*s.* net.)

NOTIONS ÉLÉMENTAIRES DE TÉLÉGRAPHIE SANS FIL ET CONSTRUCTION PRATIQUE DE POSTES RECEPTEURS (ONDES AMORTIES ET ENTRETENUES). By Jean Remaur. (Paris: *Librairie Générale Scientifique et Industrielle Desforges.* 1921. 8½″ × 5¼″. Pp. 116. Price 7 fr. 50.)

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CONTINUOUS WAVE WIRELESS TELEGRAPHY. By W. H. Eccles, D.Sc. (London: *The Wireless Press, Ltd.* 1921. $8\frac{1}{2}'' \times 5\frac{1}{2}''$. Pp. vii + 407. Price 25s.)

ARITHMETIC OF TELEGRAPHY AND TELEPHONY. By T. E. Herbert and R. G. de Wardt. (London: *Sir Isaac Pitman & Sons, Ltd.* 1921. $7'' \times 4\frac{3}{4}''$. Pp. vii + 187. Price 5s. net.)

EINFÜHRUNG IN DIE ELEKTROTECHNIK UNTER ZUGRUNDELEGUNG DER VORLESUNGEN PROFESSOR SLABYS. Revised by Otto Nairz. (Leipzig: *J. A. Barth.* $10'' \times 6\frac{1}{2}''$. Pp. viii + 415. Price M.25.20.)

EDISWAN ELECTRIC BELLS, INDICATORS, PUSHES AND ACCESSORIES. (London: *Edison Swan Electric Co., Ltd.* $11'' \times 8\frac{3}{4}''$. Pp. 36.)

A well-illustrated catalogue.

THE YEAR BOOK OF WIRELESS TELEGRAPHY AND TELEPHONY, 1921. (London: *The Wireless Press, Ltd.* 1921. $8'' \times 5''$. Pp. lxxxiv + 1355. Price 21s.)

Correspondence.

TRIODE CHARACTERISTICS WITH HIGH GRID POTENTIAL.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In the course of some measurements of triode characteristics for the purpose of constructing the characteristic surfaces of the anode and grid current, it was noticed, that with a high positive grid potential (*e.g.*, 400 volts) and a lower anode potential (*e.g.*, 300 volts) the grid current was bigger than the normal saturation value. At the same time the *anode current* was flowing in the *opposite sense* than is usual with lower grid voltages. The algebraic sum of the anode and grid current however was the normal saturation value.

No doubt this phenomenon is due to secondary electron emission from the anode, this being caused by the impact of the primary electrons coming from the hot cathode.

With the constant + 400 volts on the grid and a varying anode potential the anode current showed a falling characteristic over a big part of its course. It was very easy therefore to obtain oscillations both of audio and radio frequencies by simply inserting in the anode circuit a self-inductance shunted by a capacitance.

As this phenomenon was obtained and described by Dr. A. Hull for a specially constructed tube called by him a dynatron, it may be of interest that an ordinary hard receiving triode (we used a Mullard valve) has exactly the same physical properties.

If it is possible to keep the conditions steady enough this way of using an ordinary triode (thus having a high negative resistance to changes of anode current) as an aperiodic amplifier is certainly a noticeable simplification of Mr. Turner's kallirotron. As to the degree of constancy when used as an amplifier, however, no experiments have been carried out as yet. When used as a generator of oscillations the constancy both of amplitude and frequency is of the usual high grade.

BALTH VAN DER POL.

Physical Laboratory, Teyler's Institute,
Haarlem, Holland,
February 15th, 1921.

[We believe that it is generally known that an ordinary valve can be used to demonstrate the principle of the Dynatron. The abnormal grid and anode currents are often obtained by students determining characteristics at high grid potentials.—ED.]

"THE HETERODYNE METHOD OF WIRELESS RECEPTION, ITS ADVANTAGES, AND ITS FUTURE."

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—I should like to take issue with M. Latour regarding one point in his paper on heterodyne reception. The particular point to which I refer is his statement as follows:—

"In practice in heterodyne reception, the musical note is determined at the receiving

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station by the frequency of the local generator itself. It is not a characteristic of the transmitting station. In modulated transmission on the contrary, the received note is a characteristic of the transmitter itself.

"If we assume in the first case that a strong atmospheric discharge makes the antenna vibrate at the frequency to which it is tuned, that is to say at the frequency of the transmitting station, for a time long enough to produce beats, this discharge will of itself give rise in the receiver to the same note as that given by the transmitter. Doubtless the possibilities of this phenomenon will be reduced by receiving on a low note, as an oscillatory discharge must then last longer in order to give the same note as that of the transmitting station. The phenomenon is, however, always likely to occur.

"On the contrary in the case where the note is formed by the modulation of the transmitted current no discharge will be able to give rise to a note identical with that of the transmitter. We must therefore conclude that acoustic resonance to the received note should be more useful for protection against atmospherics when the note is given by the transmitting station itself than when it is obtained by means of a local heterodyne. Doubtless future experiment will bring out this point."

Are the facts regarding this quite correct? For years, with spark stations, which are a form of modulated C.W., we have been trying to use acoustic tuning to minimise X's with no serious effect against the X's. The X always kicked our acoustic resonator into the note with which it was tuned. As against this, heterodyne reception with acoustic resonance is having a marked effect on X reduction.

Suppose we examine an elementary case of modulation at the transmitting end.

About the simplest method of modulation is to transmit simultaneously with two wavelengths say from two C.W. stations near to one another. If the wavelengths are separated by a frequency n then a receiver without a heterodyne at a distance will hear a musical note of frequency n. If one of these stations stops sending Morse and makes a long dash, at the receiving end no difference will be noted as far as signals are concerned. X's will, however, be slightly altered by the action of the dash from the one transmitter during the spacing intervals. It can, however, be easily imagined that this dash cannot seriously affect the X, particularly when the signal is weak. Consequently there is no apparent difference between the two methods of sending.

Now the receiver could not tell if this dash sent by the one C.W. station were replaced by a heterodyne at the receiving station giving the same current and frequency to the receiving aerial particularly if the heterodyne were arranged to simulate direction as well as strength and frequency. So that obviously the modulation which M. Latour suggests is a property of the transmitting station resolves itself into a clumsy way of heterodyning—without several of the good properties of the heterodyne.

Every other type of amplitude modulation can be similarly analysed and although in many cases considerable ingenuity would have to be exhibited to get the necessary heterodyne —for instance in the case of a spark—nevertheless the result could be obtained.

Of course in the case of the two stations sending, the change in energy is twice that given by one and proper design of gear would take advantage of this, but far simpler gear would be obtained by concentrating the energy into one wave.

In the past, most of us have made the mistake of thinking that modulation, acoustic and super-acoustic, gave a definite and new character to a signal but I believe now that all the methods turn out to be merely methods of transmitting more than one wave simultaneously, sometimes, of course, particularly on short waves and with telephony, with obvious practical advantages.

If we could argue that modulation gives a character to a signal other than that given by the wavelength, then we should be able to give two modulations to the same station and receive two messages from it simultaneously. We can do this but it should be noted that such modulation produces separate wavelengths from the original wave—and why should we modulate at all?—instead of sending these separate wavelengths.

Perhaps the time has come to recognise definitely that the impulses—which is what most experiments indicate the nature of the majority of X's to be—are very similar to white light, and a signal is a narrow band on the spectrum, comparatively broad for a spark infinitely narrow for a C.W. dash of constant frequency and of infinite length, and with some disagreeable fringes when high-speed Morse is being sent. That just as Lockyer separated

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the line spectrum of the sun's atmosphere from the white light spectrum by continuous expansion of the latter by a multitude of prisms leaving the lines still unexpanded, so we are reducing our atmospherics steadily by sharper and sharper receiver resonance. The only real distinction between C.W. signals and X's is that in the first, the energy is on one wavelength and in the second it is distributed over a large part of the spectrum.

M. Latour accentuates one powerful property of the heterodyne namely that of giving what may be called a straight line law of reception, a property also of the tikker and Goldschmidt tone wheel, which property is replaceable by high frequency magnification to any desired extent, but the heterodyne has two other properties almost as valuable.

(1) What might be called the floating zero of rectification.
(2) The power of enabling one to remove one's tuning to a wavelength where circuit losses are not so troublesome.

In receivers without heterodynes, any large X or signal remains in the low-frequency inductances and condensers attached to the rectifier for a sufficient length of time to apply E.M.F.'s to the rectifier throwing it off its rectifying point. Such an effect does not matter with the heterodyne, because with careful choice of rectifier and strength of heterodyne, quite large values of low frequency potential can be applied to the rectifier without in any way impairing its rectifying properties. Those used to working with a valve rectifier fitted with a potentiometer and independent heterodyne will remember that before the heterodyne is switched on the adjustment of the sensitive point for rectification is quite sharp whereas immediately the heterodyne is put into use the potentiometer does not alter signals over quite a long range of adjustment. The property is what I call a floating zero and its effect in reception is the absence of a certain type of "wipe out" which is particularly evident if any attempt be made to tune to a modulated transmitter in the low-frequency circuits of the receiver.

The second effect probably remains as the most valuable of all the heterodyne properties. Copper, iron and dielectric losses are easier to avoid economically on long wavelengths such as those of acoustical—or nearly acoustical—frequency.

It can quite easily be seen by examining the production of a beat tone produced with a damped wave of frequency n_1 and a heterodyne, that the damping of the beat tone frequency n_2 is n_1/n_2 times the damping of the damped wave, and from this it is easy to jump to the result obtained by applying acoustical resonance to the beat circuit on the original high frequency n_1.

A circuit of damping d applied to a beat tone of frequency n_2 is the same from the resonance point of view as applying a circuit of roughly damping $d(n_2/n_1)$ to the original high frequency. The reason such a frequency circuit as the latter is not used is on account of the great difficulty in reducing circuit losses at high frequency. No doubt, finally, this will be done by means of valve reaction, but at present, on account of the fact that reaction is variable with amplitude, the method is not very useful.

In the lower frequency beat tone circuit, however, the problem is simplified by the reduced losses and with the same amount of material a total over-all damping of a comparatively small value can be obtained.

Through all this I assume that such a straight detector characteristic is chosen that the result of signals and heterodyne is $A + B \sin 2nt$ where n is the frequency of the beat tone, and this can be done in practice fairly exactly by using a heterodyne far stronger than the signal or X and a detector characteristic practically straight through any amplitude the signals or X may have.

A secondary advantage of these beat tone circuits is that real intermediate circuits are possible without enormous shielding between primary and tertiary circuits such as is necessary when one is working in high frequency alone.

A point should be noted here, that the beat tone circuit is actually in tune with two wavelengths although only in tune with one note and it is necessary to have an element of high frequency tuning to separate out the one of these two wavelengths required.

Our real limitation is the fact that the Morse turns our line spectrum into a band and renders the finest tuning impossible, difficulties increasing in proportion to the speed of transmission and the wavelength used. When analysed out, no method such as scissors sending will improve the case although some slight improvement would undoubtedly come

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by using two wavelengths—one for sending dots and the other for dashes—making all the characters an equal length, a system quite easy with the arc or valve, but not very easy with the alternator.

When using the heterodyne without acoustic resonance, the ear does our tuning for us by separating out the musical from the unmusical sounds but it is now being seriously replaced by super-resonance and machine recording. A well-known American wireless expert once expressed the opinion to me that it was a pity our ears could not be put in opposition or cascade as it would render them still more useful.

Owing to the variability of transmitted wavelengths from the alternator on long waves and from arcs on short waves and even with valves on all wavelengths unless fair precautions are taken, we have not yet used to the full extent all the possibilities of the heterodyne method of reception but to the steadiness of good valve circuits on medium powers and wavelengths is due most of the advance that has been made in practice. I attach much more importance to this absolute constancy of wavelength than to almost any other point at the present time and until a new transmitter is invented, which has, whatever its other advantages, a wavelength constancy equal to that which can be given by the valve (although incidentally, it is not always given by the valves one hears), the latter will hold the field.

Until some genuine method is discovered of getting a new character into the signal when we have used our resonance to its practical limits, we have only directional properties to fall back upon, any development of which will probably be up against serious night-time difficulties. In various attempts to give this new property, the question of modulation of the frequency has been seriously considered by us. If the frequency of the transmitted oscillation could be varied at a frequency of the same order as the first frequency or preferably higher—but with an incmomensurable ratio between the two frequencies say by some method of varying inductance or capacity in a valve circuit and a receiver were constructed to receive this, by some method of varying inductance or capacity in the receiver circuit —not quite synchronously, a kind of heterodyne—a further property of signals might be developed.

Such a system seems to have quite new properties, if it could be made practically workable and if any authority could ever be persuaded that it would not jam the rest of the earth's wireless.

To illustrate exactly my meaning, I will state a case in wavelength. The middle wavelength of the system could be 10,000 metres ($f = 30{,}000$) and this wavelength could be varied from 8,000 to 12,000 metres at a frequency of $\pi \times 10{,}000$ (the π merely being inserted to render the ratio incommensurable).

If the scheme were carried out correctly, it would not seriously interfere with any sharply-tuned simple harmonic receiver as it would rush so quickly through the wavelength that no effect would be produced. The receiver would, conversely, not be interfered with by any ordinary simple harmonic transmitter. What would happen in the case of impulses? I am inclined to think that the final result of combining this new property with the older sharp-tuning properties would be a still further reduction of X's and I base this on the broad reasoning that as impulses are analysable into a sum of an infinite number of continuous waves of different wavelengths and as the new type of wave is not analysable into any combination of simple harmonic motions, therefore the X's will not get into the new receiving circuits. The limitation again being the length of the Morse characters but of course this question can be put to the test of the mathematician before ever it can reach a practical test.

H. J. ROUND.

Chelmsford,
February 16th, 1921.

DIRECTION FINDING.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In the RADIO REVIEW for November, 1920, Major Prince criticised Captain Robinson's article on a "Method of Direction Finding." On page 699 speaking of Captain Robinson's method he says "the real essence of his method is the substitution of switching for rotation and that by the ingenious method of connection, difficulties of phasing are avoided." This

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statement, and the admission on the same page that there is some basis for the claim that equality of signals is a better subject of observation than the minimum strength, are together an indication of the novelty and utility of the invention. To these can be added the fact, that previous to the introduction of the method, no satisfactory results had ever been obtained in aircraft by any one else.

The rest of Major Prince's *critique* of Captain Robinson's article is interesting, and in some respects even entertaining, but as it is a piece of "special pleading" it need not be taken very seriously. Indeed how can one take seriously such statements as the following (on p. 696, line 25): "Except for secondary considerations (such as convenience; or accuracy) it is immaterial whether observations are made to the maximum or minimum," and on p. 697, line 20, "This constant signal . . . takes no part in helping to determine direction." In the first quotation he says that direction may be obtained by observation of a maximum, in the second that a maximum observation is useless. He cannot have it both ways, and the statement that "convenience and accuracy" are "secondary considerations" is somewhat strange from the only important point of view, namely that of practical navigation. Major Prince notes that in the Handley Page which was entered for the transatlantic flight in 1919, two years after the date of Robinson's patent, a modified Bellini-Tosi system was used with success. He does not mention however that the success of the first transatlantic flight, that of the U.S.A. flying boat N.C. 4, was largely due to the use of Dr. Robinson's apparatus, although in the published description in the *Proc. Inst. Radio Engineers* the invention has been ascribed in error to American officers.

The patents which Major Prince quotes, namely his own of 1912 and Captain Round's of 1909, have no real relation to Robinson's as the bearings given by both of them involve ambiguities far more serious than the 180° ambiguity. Thus in Round's patent, Fig. 1, it is obvious that equality of signals will be obtained not only in both senses of the direction shown in the drawing, but also at the other two intersections of the curves. In Major Prince's patent where the method of reducing signals to equality is employed, it is uncertain whether the angle determined relative, say, to the north-south axis should be east or west of this axis. Major Prince is therefore right in laying no great stress on these patents.

The claim that the Bellini method is "basic" shows some confusion of thought. The single turning coil is basic, as basic as the theory of electromagnetic induction, but the Bellini apparatus was no doubt invented because at that time no detector was sufficiently sensitive to give results on a single coil of manageable dimensions. The Bellini was thus a derived method, depending ultimately on the single coil, but with fixed collectors which allowed of the coil being moved in a stronger field than that of the waves from the transmitter. Mr. Round showed in his paper at the Institution of Electrical Engineers what a formidable train of errors becomes possible on account of these more complicated circuits. Even from the "minimum" point of view the Bellini method is not basic, for the truth is that except, perhaps, when used on a signal of just the right strength in a silent cabinet, the minimum method is a misnomer, and is in reality always carried out by a rough comparison of signal strengths on both sides of the minimum; but as in moving the coil from a comfortably audible signal on one side, to a similar one on the other, the signal passes through a gradation of decreasing and increasing strengths, the comparison can only be a rough one and by no means as accurate as in Robinson's method where the successive signals are of definite strength and without intervening variations.

J. ERSKINE-MURRAY.

Directorate of Research, Air Ministry, London.
February 17th, 1921.

ERRATUM.

Page 152, *line* 22, *for* log ax *read* $\log_e ax$.

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THE RADIO REVIEW

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Editor:
PROFESSOR G. W. O. HOWE, D.Sc., M.I.E.E.
Assistant Editor:
PHILIP R. COURSEY, B.Sc., A.M.I.E.E.

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Editor: Prof. G. W. O. HOWE, D.Sc., M.I.E.E. Asst. Editor: PHILIP R. COURSEY, P.Sc., A.M.I.E.E.

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THE RADIO REVIEW

INFORMATION FOR CONTRIBUTORS

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THE
RADIO REVIEW

VOL. II MAY, 1921 NO. 5

Editorial.

The paper by Commander Pession of the Italian Navy which we publish in this issue is closely allied with that by his colleague Professor Vallauri which was completed in our last issue. The two form a valuable contribution to our knowledge of the subject of radiation measurement. Doubtless measurements of a similar character will be made on all transmitting stations of any importance. Although not yet published we know that much work of a similar nature has been done by other workers. In 1913 we determined the effective resistance of the aerial at the City and Guilds Engineering College by means of a Duddell thermogalvanometer and inserted resistance, using long dashes from the Eiffel Tower as the source of power. We also worked out and communicated to the International Committee at Brussels the field strength of the Eiffel Tower signals in London, assuming effective heights for the two aerials.

The Effect of the Heaviside Layer.—In the current issue we publish the concluding portion of Mr. Eckersley's paper on this subject, the first part of which appeared in the February issue. In our opinion this paper constitutes one of the most important contributions yet made to this difficult but interesting subject. It goes far to explain the abnormal phenomena observed in connection with direction finding by means of wireless telegraphy and makes it highly desirable to carry out systematic experiments to check Mr. Eckersley's conclusions. In justice to the author, and to those readers who would have welcomed a more detailed mathematical investigation of the points raised, we should mention that at our request Mr. Eckersley has omitted a considerable portion of the more mathematical part of the paper.

The Solar Eclipse.—During the recent solar eclipse, observations of the strength of signals and atmospherics were made by a number of stations under the direction of the Post Office. We are pleased to be able to publish the result of these observations in this issue. The general effect seems to have been a partial return to night conditions. It would be of interest to learn if any other observers, especially those engaged in long distance work, noted any changes in signal strength.

Increase in Price of the "Radio Review."—When the RADIO REVIEW was first published the cost of everything connected with printing and publishing was very high, but it was anticipated that we had then reached the peak of the curve and that costs would gradually fall. These hopes have

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unfortunately been falsified and costs have continued to rise. We are therefore reluctantly compelled to increase the price of the RADIO REVIEW. We feel sure however that after due consideration and a comparison of present and pre-war values our readers will agree that the increase is not an unreasonable one. The new price will take effect with the June issue.

Nauen and Togoland.—Although the article with this title, the translation of which we complete in this issue, deals largely with the brief but striking history of the Togoland Station of Kamina, it contains much of wider interest. The German plans for the development of an imperial chain and the details of the financial arrangements made between the German Government and the Telefunken Company for the erection of the stations are discussed with apparent frankness. It is stated in the current number of *Radioélectricité* that the tropical vegetation has all but obliterated the traces of the Kamina Station.

Eclipse of the Sun, April 8th, 1921. Effects Produced at Wireless Stations.

By F. ADDEY, B.Sc.

In order to observe if any abnormal phenomena were produced during the eclipse, arrangements were made for a special watch to be kept at certain of the wireless stations under the control of the Post Office. The stations concerned were Wick, Stonehaven, Cullercoats, Caister, North Foreland, Niton, Lands End, Fishguard, Seaforth and Devizes.

The total period of the eclipse, at Greenwich, was from 7.35 a.m. to 10.5 a.m., G.M.T. The maximum occurred there at 8.47 a.m. At other places the times of first and last contact and of maximum were different, but these differences were so small that as far as the observations recorded below are concerned, they may be neglected.

At most of the stations dealing with the ordinary ship-and-shore communication on 600 metres, no change, either in the strength of signals or in the strength or frequency of atmospherics, was observed. At Fishguard, however, between 8.28 a.m. and 9.36 a.m., signals improved both in clearness and strength. This effect was more pronounced with the signals from distant stations than with those from nearer stations.

At Wick, although no unusual daytime ranges were observed, there was during the period of the eclipse a pronounced under-current of faint signals which is not normally present during the day.

At Devizes the conditions observed during the eclipse were practically identical with those usual during the night. With a receiver consisting of one high frequency amplifier, a rectifying valve, and two note magnifying valves, the average strength of signals from Warsaw during the day is 7. Warsaw works on a wavelength of 2,100 metres, using spark transmission. During the

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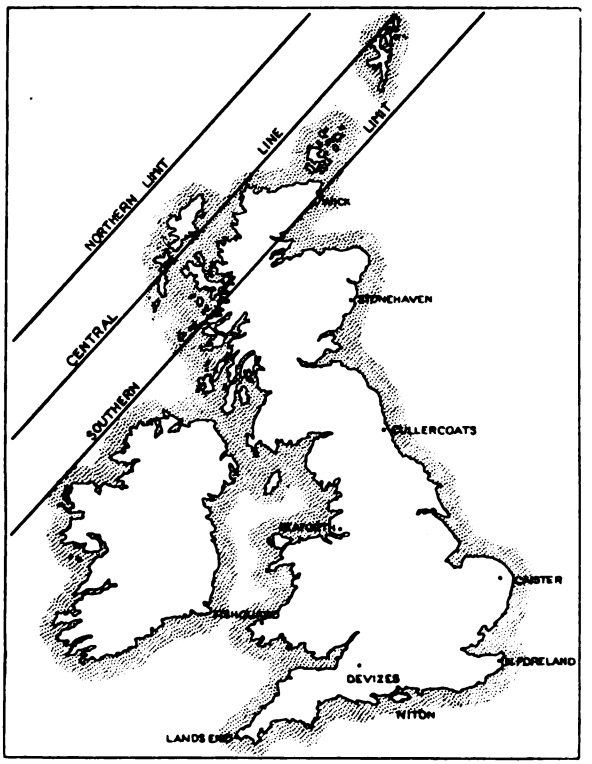
eclipse these signals increased to maximum strength, which is the usual night condition, and after the eclipse they returned to their normal daylight strength.

Devizes also observed an increase in the strength of signals received from various French military wireless stations. These stations were working on a wavelength of about 2,000 metres, using continuous waves.

An increase in atmospherics was observed at several stations during the eclipse.



Map showing Positions of the Stations and Path of the Eclipse.

Before the eclipse atmospherics were practically absent at all the observing stations. At Fishguard slight atmospherics were observed between 8.20 a.m. and 9.36 a.m. At Devizes atmospherics came on at the commencement of the eclipse, and ceased when the eclipse was over.

At Wick atmospherics gradually became louder and more numerous during the eclipse till at about 8.56 a.m. there was a continuous crackle. This then decreased and after the eclipse the atmospherics disappeared.

A similar growth in the number and strength of atmospherics was observed at Caister, and there also the atmospherics disappeared after the eclipse.

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The Measurement of the Effective Height of Aerials: a Special Case.

By Commander G. PESSION.

1. In the practice of radiotelegraphy the determination of the effective height of an aerial must now be regarded as a normal measurement. Such measurements are valuable for the rational design and modification of the aerial with respect to the characteristics of the H.F. generating plant, and, if repeated periodically, afford a control of the condition of the station.

To make the determination one measures the current received in a coil aerial of known dimensions, situated at a certain distance from the transmitting aerial. This distance should be such that absorption effects are negligible, but not so small that direct induction is appreciable.

From the theory of Hertz we have

$$hh_r = \frac{I_r}{I} \cdot \frac{d \,.\, R \,.\, \lambda}{120\pi} \quad \ldots\ldots\ldots \quad (1)$$

in which h = effective height of transmitting aerial in kilometres.

h_r = effective height of receiving aerial in kilometres.

d = distance between stations in kilometres.

λ = wavelength in kilometres.

I = current in transmitting aerial in amperes.

I_r = current in receiving aerial in amperes.

R = total resistance of receiving circuit in ohms.

In a frame or coil aerial we can put

$$h_r = 2\pi \frac{S_r}{\lambda} \cos \alpha$$

where S_r = total effective area of receiving coil in m^2.

α = angle between the vertical plane of the coil and the vertical plane through the two stations.

Substituting this in (1) we get

$$h = \frac{I_r}{I} \cdot \frac{dR\lambda^2}{240\pi^2 S_r \cos \alpha} \quad \ldots\ldots\ldots \quad (2)$$

Equations (1) and (2) refer to the now general case of undamped waves.

The measurement of I_r can be made with a thermogalvanometer or with a thermocouple connected to a suitable galvanometer.

2. To verify the effective height of the Italian Naval Station at Rome, I have used a simple method which I think is worthy of description since it may be found very useful when one has a sufficient number of stations in the vicinity. This will generally be the case at a naval base, where there are

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always several ships furnished with wireless apparatus and usually a powerful coast station.

If one has three stations A, B, C, and if the suffixes a, b, c, be used to distinguish symbols referring to the respective stations, we have when A transmits to B

$$h_a h_b = \frac{I_r}{I} \frac{\lambda_a d_{ab} R_b}{377} \quad \ldots \ldots \ldots \quad (3)$$

when B transmits to C

$$h_b h_c = \frac{I_r}{I} \frac{\lambda_b d_{bc} R_c}{377} \quad \ldots \ldots \ldots \quad (4)$$

and when C transmits to A

$$h_c h_a = \frac{I_r}{I} \cdot \frac{\lambda_c d_{ca} R_a}{377} \quad \ldots \ldots \ldots \quad (5)$$

From these three equations we can determine the three unknowns h_a, h_b, h_c.

3. With the power and distance of the Rome Station the measurements can be made very simply by means of a Duddell thermogalvanometer.

The measurement of the resistance was made by introducing step by step into the accurately tuned aerial a known resistance R'; then

$$R = R' \frac{I_r'}{I_r - I_r'}$$

in which I_r is the received current without the inserted resistance R' and I_r' that with it.

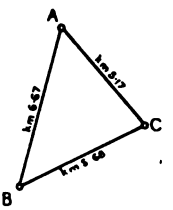

FIG. 1.

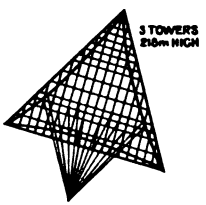

FIG. 2.

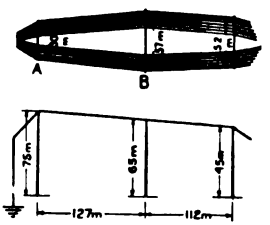

FIG. 3.

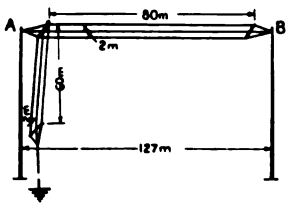

FIG. 4.

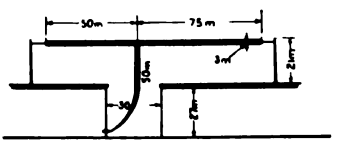

FIG. 5.

Fig. 1 shows the distances between the three aerials (measured to their centres), while Figs. 2, 3, 4 and 5 show their construction and principal dimensions.

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1st Test.—Transmitting from B to A.

$I_r = 95{\cdot}10^{-3}$ A. $I = 18{\cdot}0$ A. $\lambda = 3{\cdot}2$ km.

$R = 12{\cdot}72$ ohms. $d = 6{\cdot}67$ km. $h_a h_b = 0{\cdot}0038$.

The following series of readings shows the reliability of the readings.

I_r	I_r'
95·3	78·1
95·5	77·7
95·0	78·0
95·2	77·8
95·0	77·6
94·8	77·7
94·7	77·5
Means: 95·1	77·8

$R' = 2{\cdot}83$.

$R = 2{\cdot}83 \dfrac{77{\cdot}8}{17{\cdot}3} = 12{\cdot}72$.

2nd Test.—Transmitting from C to A.

$I_r = 49{\cdot}10^{-3}$ A. $I = 10{\cdot}6$ A. $\lambda = 3{\cdot}15$ km.

$R = 12{\cdot}90$ ohms. $d = 5{\cdot}17$ km. $h_c h_a = 0{\cdot}00257$.

3rd Test.—Transmitting from C to B.

$I_r = 24{\cdot}5{\cdot}10^{-3}$ A. $I = 13{\cdot}0$ A. $\lambda = 1{\cdot}8$ km.

$R = 10{\cdot}30$ ohms. $d = 5{\cdot}68$ km. $h_c h_b = 0{\cdot}000526$.

From which

$h_a = 136$ m; $h_b = 27{\cdot}9$ m; $h_c = 18{\cdot}8$ m.

It is interesting to note that Station C has a **T** aerial erected above a large factory, the actual height of the horizontal portion above the roof being about 20 metres. Station B has two aerials, a large and a small; the measurements were made on the small one. A fourth test using the large aerial gave the following results:—

$h_b' = 40{\cdot}3$ m with the small aerial insulated.

$h_b' = 35{\cdot}6$ m with the small aerial put to earth.

4. Another test was made after the small B aerial had been modified. Station C was not employed, but a temporary aerial was erected with a length of about 200 metres and a height of about 10 metres; it was situated at a distance

$d = 19{\cdot}6$ km from A

and $d' = 24{\cdot}7$ km from B.

A Duddell thermogalvanometer was employed with the following results:—

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Transmitting from A

$I = 54$ A; $I_r = 0{\cdot}212{\cdot}10^{-3}$ A; $R = 585$ ohms; $\lambda = 6{\cdot}08$ km.

Transmitting from B

$I' = 20$ A; $I_r' = 0{\cdot}1428{\cdot}10^{-3}$ A; $R' = 155$ ohms; $\lambda = 2{\cdot}40$ km.

The above values of R were obtained with a 100 ohm heater and in the case of A, an additional 400 ohms was inserted to reduce the current.

From the above it can be seen that

$$\frac{h_a}{h_b} = \frac{I_r I' \lambda_a d}{I_r' I \lambda_b d'} \cdot \frac{R}{R'} = 4{\cdot}14.$$

By transmitting from B to A the following results were obtained:—

$I_r = 92{\cdot}10^{-3}$ A; $I = 18$ A; $d = 6{\cdot}67$ km.

$R = 15{\cdot}4$ ohms; $\lambda = 3{\cdot}15$ km; $h_a h_b = 0{\cdot}00439$ km^2.

Hence $h_a = 135$ m and $h_b = 32{\cdot}6$ m.

In this test a resistance of 3 ohms was inserted in the A aerial to reduce the received current; the real value of the antenna resistance was therefore 12·4 ohms which agrees very well with the value 12·7 ohms previously determined. The difference is to be attributed to the different inductances employed for tuning in the two tests, which moreover took place with an interval of four months. In these tests a Duddell thermogalvanometer with a heater of 1·77 ohms was inserted in the antenna. One sees that as a consequence of the alterations to aerial B its effective height has been increased.

The two determinations of h_a are in perfect agreement and correspond closely with the value of 138 m determined three years ago by Prof. Vallauri by direct measurement on a coil aerial.

The Effect of the Heaviside Layer on the Apparent Direction of Electromagnetic Waves.

By T. L. ECKERSLEY, B.A., B.Sc.

(*Concluded from page 65 of February issue.*)

We will choose rectangular axes, the axis of z perpendicular to the plane of the earth, the axis of x in the direction of the ray, and the axis of y in the horizontal plane perpendicular to the ray. The following symbols will be used throughout the paper:—

X, Y, Z = Electric forces in the x, y, z directions respectively.

α, β, γ = Magnetic forces in the x, y, z directions respectively.

α = Re-combination constant.

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$\left.\begin{matrix} l, n \\ l, -n \\ l', n' \end{matrix}\right\}$ = Direction cosines of the normals to the wavefronts of rays (2), (3) and (4).

E = E.M.F. induced in a closed circuit.

K' = Specific inductive capacity of earth.

μ = Permeability of earth.

σ = Conductivity of earth.

$\nu = 2\pi/\lambda$.

λ = Wavelength.

c = Velocity of light.

$p = 2\pi \times$ frequency of the electric waves.

The suffixes are explained in the course of the paper.

The following rays are considered (Fig. 4), and for convenience are named as follows :—

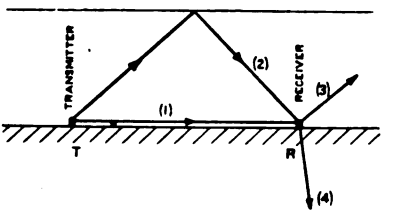

FIG. 4.

No. (1) is called the " direct ray."

No. (2) is called the " incident ray."

No. (3) is called the " reflected ray " (at the surface of the earth).

No. (4) is called the " refracted ray " (in the earth).

A wave is to be considered as polarised in the plane of its electric force. In general there will be two waves polarised in perpendicular planes :

(a) With the electric force in a vertical plane perpendicular to the earth, in which case $\alpha = \gamma = Y = 0$.

(b) With the electric force parallel to the surface of the earth, in which case β, X and Z are all zero.

Case (a) may be excluded from consideration as $\alpha = 0$, which means that there is no magnetic force in the direction of the ray.

In general there will be only three rays to consider at the receiving station : (1) the incident ray, (2) the reflected ray, and (3) the refracted ray.

These are :—

Incident ray.	Reflected ray.	Refracted ray.
$Y = Y_0 \epsilon^{j\nu(lx + nz - ct)}$	$Y = Y_r \epsilon^{j\nu(lx - nz - ct)}$	$Y = Y' \epsilon^{j\nu'(l'x + n'z - ct)}$
$\alpha = \alpha_0 \epsilon^{j\nu(lx + nz - ct)}$	$\alpha = \alpha_r \epsilon^{j\nu(lx - nz - ct)}$	$\alpha = \alpha' \epsilon^{j\nu'(l'x + n'z - ct)}$
$\gamma = \gamma_0 \epsilon^{j\nu(lx + nz - ct)}$	$\gamma = \gamma_r \epsilon^{j\nu(lx - nz - ct)}$	$\gamma = \gamma' \epsilon^{j\nu'(l'x + n'z - ct)}$

. . (1)

Now in the upper medium, *i.e.*, the air above the surface of the earth, the total electric force is :—

$$Y = \epsilon^{j\nu(lx - ct)} (Y_0 \epsilon^{j\nu nz} + Y_r \epsilon^{-j\nu nz})$$

$$\text{or } Y = \epsilon^{j\nu(lx - ct)} \{(Y_0 + Y_r) \cos \nu nz + j (Y_0 - Y_r) \sin \nu nz\} \quad . \quad . \quad (2)$$

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Now an application of the laws of metallic reflection shows that in this case

$$(Y_0 + Y_r) = \frac{2nY_0}{\left(\frac{n}{\mu'} + \frac{S}{\mu'} + \frac{jS'}{\mu'}\right)} \text{ and } (Y_0 - Y_r) = \frac{2Y_0\left(\frac{S}{\mu'} + \frac{jS'}{\mu'}\right)}{\left(\frac{n}{\mu} + \frac{S}{\mu'} + \frac{jS'}{\mu'}\right)} \quad . \quad . \quad (3)$$

Where

$$S = -\frac{1}{\sqrt{2}}\left\{R + (\mu'K' - 1) + n^2\right\}^{\frac{1}{2}} . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

$$S' = -\frac{1}{\sqrt{2}}\left\{R - (\mu'K' - 1) - n^2\right\}^{\frac{1}{2}} . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

$$R = \left[\left\{\left(\mu'K' - 1\right) + n^2\right\}^2 + \frac{\sigma^2\mu'^2}{\nu^2}\right]^{\frac{1}{2}} . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

μ' permeability of the earth.
K' specific inductive capacity of the earth.
σ specific conductivity of the earth.

Now

$$-\mu\frac{\partial\alpha}{\partial t} = \frac{\partial Y}{\partial z} = \epsilon^{j\nu(lx - ct)}\{-(Y_0 + Y_r)\nu n \sin \nu nz + j(Y_0 - Y_r)\nu n \cos \nu nz\}. \quad (7)$$

remembering the values of $(Y_0 + Y_r)$ and $(Y_0 - Y_r)$ we see that when n is small the latter term is the most important, the former being of the order n^2 and the latter of the order νn. In any case the expression vanishes with n so that when the wave is propagated parallel to the surface of the earth there is no flux α and no E.M.F. induced in a loop in the yz plane (as before stated).

We may therefore infer from the experimental existence of this E.M.F. that "n" is not zero (excluding the ray reflected in the horizontal plane for the reasons before stated), *i.e.*, that there is a ray which makes an appreciable angle with the surface of the earth. The argument of course only refers to plane waves propagated over a plane surface, but the argument is obviously true to the first order where the radius curvature of the wave front is large compared with the wavelength (and such are all the cases met with in practice).

EXPERIMENTAL TEST FOR THE RAY REFLECTED IN A VERTICAL PLANE, AND POLARISED IN HORIZONTAL PLANE.

The experiment consists in isolating this ray and comparing its intensity with that of the direct ray, at the same time noting the error in the bearing. In order to do this a closed horizontal receiving aerial was used.

It follows from the previous analysis (and Sommerfeld's more general analysis*) that for a ray propagated over the surface of the earth γ the vertical magnetic force is zero, and therefore there is no flux linked with a closed aerial in a horizontal plane, and no E.M.F. can be induced in it by such a ray. But for the ray reflected in the vertical plane (which for the sake of

* *Annalen der Physik*, 28, p. 665, 1909.

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brevity we shall now call the indirect ray) the E.M.F. induced is proportional to

$$-\mu\frac{\partial\gamma}{\partial t} = -\frac{\partial Y}{\partial x} = -jvl(Y_0 + Y_r) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$= \frac{-jvl\eta\gamma_0}{\left\{\frac{n}{\mu} + \frac{S}{\mu} + \frac{jS'}{\mu}\right\}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

so that the E.M.F. induced is proportional to the angle of elevation of the ray when this is small and to the intensity of the ray itself.

The arrangements used for this comparison were as follows (Fig. 5) :—

TABLE I.—OBSERVATIONS MADE ON TRANSMITTING STATION AT DAMASCUS.

Date.	$\frac{1}{2}\theta_1$	tan $\frac{1}{2}\theta_1$	θ	tan θ	Remarks.
June 16th	23° G.	0·42	20° flat.	0·36	Taken at night.
,,	20° G.	0·36	15° flat.	0·27	,, ,,
June 17th	4° V.G.	0·07	0°	0	Three-day observation.
,,	32° G.	0·625	20° G.	0·36	Night.
,,	15° V. flat.	0·27	22° F.	0·34	,,
,,	27° F.	0·51	16° F.	0·29	,,
,,	21° G.	0·38	9° F.	0·16	,,
,,	18° G.	0·32	6·5° G.	0·11	,,
,,	16° V. flat.	0·29	1° V. flat.	0·02	,,
,,	19° V. flat.	0·34	0° V. flat.	0	,,
,,	10° } V. flat.	{ 0·18 }	−4° V. flat.	0·07	,,
,,	9° }	{ 0·16 }			
,,	16° to } fair.	{ 0·29 }	0° V. flat.	0	,,
,,	20° }	{ 0·36 }			
,,	20° fair.	0·36	1° V. flat.	0·02	,,
June 18th	10° to 32° varying.	0·18 to 0·625	9° G.	0·16	,,
,,	24° to 32°	0·445 to 0·625	24·5° flat.	0·46	,,
,,	25°	0·47	11° F.	0·19	,,
,,	15° G.	0·27	6° F.G.	0·10	,,
,,	6° G.	0·10	3° V.G.	0·05	,,
,,	12°	0·21	10° G.	0·18	,,
,,	9° G.	0·16	3° G.	0·05	,,
,,	7° G.	0·12	3° G.	0·05	,,
,,	5° G.	0·09	2° V.G.	0·03	,,
,,	6° G.	0·10	2° V.G.	0·03	,,
,,	8° V.G.	0·09	0° V.G.	0	,,
,,	4·5° } V.G.	{ 0·08 }	0·5°	0·01	,,
,,	5·0° }	{ 0·09 }			
,,	13° flat.	0·23	7° G.	0·12	,,
,,	15° V. flat.	0·27	11° F.	0·19	,,
,,	22° to 17° flat.	0·40 to 0·30	17° F.	0·30	,,
,,	11° flat.	0·19	5° G.	0·09	,,
,,	17° G.	0·30	5° G.	0·09	,,

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The vertical loop, consisting of a frame 5 feet 6 inches × 7 feet wound with twenty turns of bare copper wire, was placed at the centre of a closed horizontal loop (about 40 yards square and 12 feet above the surface of the ground). The terminals of the loop and horizontal aerial were each brought to the terminals of one of the fixed coils of the compass or goniometer, and the search coil of the compass was connected to the receiving apparatus. A

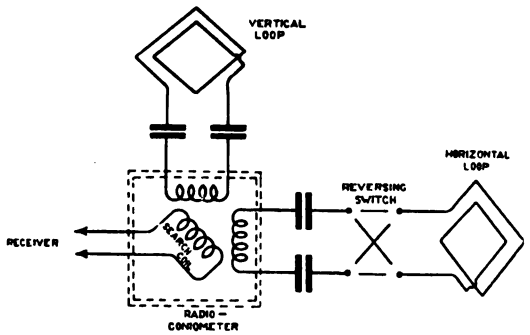

FIG. 5.

reversing switch was placed in the horizontal aerial. If the currents in the loop circuit and horizontal aerial circuit are in phase the resultant magnetic field (in the goniometer) will always lie along some fixed direction, and it will be possible to find a position of the search coil where there is no flux linkage and no signals.

Thus if θ_1 is the difference in position of the two minima when the horizontal aerial is reversed

$$\tan \tfrac{1}{2}\theta_1 = \frac{\text{current induced in horizontal aerial}}{\text{current induced in loop}} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

In the accompanying table (I.) this quantity $\frac{1}{2}\theta_1$ (*i.e.*, the measure of the intensity of the indirect ray) is compared with θ, the error in bearing which is taken either immediately before or after the measurement of θ_1.

The curve (Fig. 6) shows $\tan \frac{1}{2}\theta_1$ plotted against $\tan \theta$ and a glance reveals the fact that they are roughly proportional, *i.e.*, a bad bearing is associated with strong signals in the horizontal aerial. The points should not necessarily lie on a single curve as the error in bearing is only a measure of the disturbing E.M.F. when this is in phase with the main E.M.F. (When the E.M.F.'s are not in phase a slight distuning of the horizontal aerial will produce a large change of phase in the current, so that a suitable readjustment of the tuning condenser will bring the currents into phase again. The measured current in the horizontal aerial will then be slightly too small.)

The points marked in Fig. 6 with a full dot "•" are those for which the minima on the frame and the compass are both well defined. These lie fairly well on a straight line (see Fig. 7); the slope of this line (*i.e.*, $\tan \frac{1}{2}\theta_1/\tan \theta$) should be a function of the electrical constants of the horizontal and loop aerials, and the conductivity, resistivity and inductivity of the earth.

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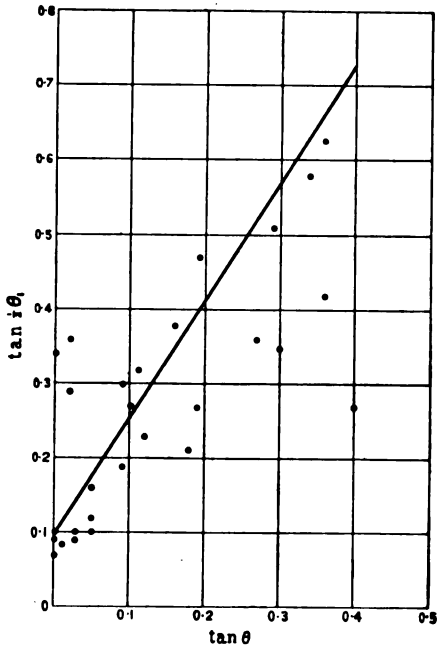

FIG. 6.

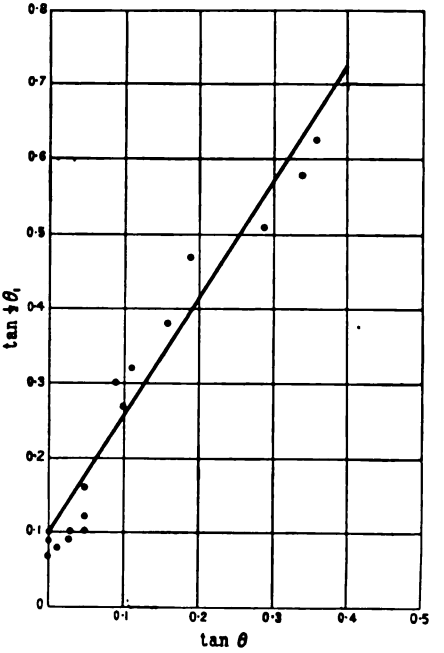

FIG. 7.

Let E_1 = the E.M.F. induced in the loop when this is parallel to the direction of the ray.

E_1' = the E.M.F. induced in the loop when this is perpendicular to the direction of the ray.

E_h = the E.M.F. induced in the horizontal aerial per unit area.

A_h = area of horizontal frame.

A_1 = area of loop × number of turns.

E_hA_h = E.M.F. induced in horizontal aerial.

E_1A_1 = maximum E.M.F. induced in loop.

R_h = effective resistance of horizontal aerial.

R_1 = effective resistance of horizontal loop.

Then
$$\tan\theta = \frac{E_1'}{E_1} \quad \ldots\ldots\ldots\ldots \quad (11)$$

and at the same time
$$\tan\tfrac{1}{2}\theta_1 = \frac{E_hA_hR_1}{E_1A_1R_h} \quad \ldots\ldots\ldots\ldots \quad (12)$$

so that
$$\tan\tfrac{1}{2}\theta_1/\tan\theta = \frac{E_h}{E_1'} \times (\text{constant}) \quad \ldots\ldots \quad (13)$$

where this constant depends only on the electrical constants of the circuits.

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Now E_h and E_1' depend only on the ray reflected in the vertical plane, in fact

$$E_h = -\frac{\mu\partial\gamma}{\partial t} \quad \ldots\ldots\ldots (14)$$

$$E_1' = -\frac{\mu\partial\alpha}{\partial t} \quad \ldots\ldots\ldots (15)$$

and since the ray polarised in the Y plane (Y, α, γ), can only affect these two aerials the ratio of $\partial\gamma/\partial t$ to $\partial\alpha/\partial t$, $\frac{E_h}{E_1'}$ can only be dependent on the ratio of the incident and reflected rays, *i.e.*, upon the constants of the ground and the angle of elevation of the incoming ray.

In fact, from (3),

$$E_h = -\frac{j\nu l n Y_0}{\left\{\frac{n}{\mu'} + \frac{S}{\mu'} + \frac{jS'}{\mu'}\right\}} \quad \ldots\ldots\ldots (16)$$

$$E_1' = \frac{j\nu n Y_0 2\left(\frac{S}{\mu'} + \frac{jS'}{\mu'}\right)}{\left\{\frac{n}{\mu'} + \frac{S}{\mu'} + \frac{iS'}{\mu'}\right\}} \quad \ldots\ldots\ldots (17)$$

so that

$$\frac{E_h}{E_1'} = -\frac{l}{2\left(\frac{S}{\mu'} + \frac{jS'}{\mu'}\right)} \quad \ldots\ldots\ldots (18)$$

l being practically unity

where

$$S = -\frac{1}{\sqrt{2}}\left\{R + (\mu'K' - 1) + n^2\right\}^{\frac{1}{2}}$$

$$S' = -\frac{1}{\sqrt{2}}\left\{R - (\mu'K' - 1) - n^2\right\}^{\frac{1}{2}}$$

$$R = \left[\left\{(\mu'K' - 1) + n^2\right\}^2 + \frac{\sigma^2\mu'^2}{\nu^2}\right]^{\frac{1}{2}}$$

μ', σ, K', n having the same significance as before. If E_1 and E' are in phase (*i.e.*, if a good minimum is obtained with the rotating loop) E_h and E_1 are practically 45° out of phase (since $S = S'$ approximately), if then the horizontal aerial is adjusted so as to give a good balance on the compass

$$\tan\tfrac{1}{2}\theta_1/\tan\theta = \frac{1}{\sqrt{2}}\frac{E_h}{E_1} \times C_1 = \frac{1}{\sqrt{2}}\frac{1}{2}\frac{1}{\frac{S}{\mu'} + \frac{jS'}{\mu'}} \times C_1 \quad \ldots\ldots (19)$$

$$= \frac{1}{4}\frac{1}{S} \times C \text{ nearly} \quad \ldots\ldots\ldots (20)$$

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Where C is the constant $\frac{A_h R_1}{A_1 R_h}$, the quantity C can be roughly measured; we then get a rough value for S from this last equation.

The value for S so obtained was about 5, and this quantity calculated from the approximate constants of the earth is about 7, so that agreement of the right order is obtained. Only a rough agreement can be expected, firstly because of the uncertainty of phase of the various factors, secondly because of the difficulty of getting sufficiently well defined minima, and thirdly because the electrical constants of the earth are not known with any degree of accuracy.

A slight residual E.M.F. induced in the horizontal aerial remains even in the daytime. This may be due to slight tilting of the horizontal aerial, or it may represent a real residual reflection or refraction at the upper layer. There is evidence that this exists even in the daytime, for the mathematical researches of G. N. Watson indicate that the pure diffraction of waves round the earth is not sufficient to account for the observed results of Austin,* and that it is necessary to assume a reflecting layer in order to bring the theory into accordance with practical observations.

The values of tan θ will give us an estimate of the relative intensities of the reflected rays and horizontal direct ray,

for $$\tan\theta = -\frac{\frac{\mu\partial\alpha}{\partial t}}{\frac{\partial z}{\partial x}} = -\frac{n2\left(\frac{S}{\mu'}+\frac{jS'}{\mu'}\right)}{\left(\frac{n}{\mu}+\frac{S}{\mu'}+\frac{jS'}{\mu'}\right)}\cdot\frac{Y_0}{Z_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

and when n is small compared with S and S' as it always is, tan θ is very nearly $\frac{2nY_0}{Z_0}$ now Z_0 includes the electric force Z_1 in the direct ray and the electric force Z_1' in the indirect incident ray.

(Of course Z_1 and Z_1' may be 180° out of phase so that the effect of the deviating electric force is accentuated in this case, even a small amount of energy reflected will produce large effects.)

If Z_1' is zero

$$\tan\theta = \frac{2nY_0}{Z_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

or $$\frac{Z_1}{Y_0} = \frac{2n}{\tan\theta}$$

now n is of the order 0·1 and tan θ varies between 0·2 and 0·3 so that Z_1 and Y_0 are of the same order of magnitude, *i.e.*, the direct ray and indirect ray are of the same order of intensity at night.

The indirect ray (polarised in the horizontal plane, *i.e.*, with the electric force horizontal (Y, α, γ)) may be produced by radiation from an asymmetrical

* G. N. Watson, *Proceedings of the Royal Society*, 95A, p. 83, 1918; also Van der Pol, *Philosophical Magazine*, 38, p. 365. September, 1919.

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inverted L type aerial, for the radiation from such an aerial in any direction, except in the horizontal plane, has a component of the electric force parallel to the horizontal portion of the aerial, so that if this transmitting aerial has the horizontal part or a component part of the horizontal part of the aerial in the yz plane, the indirect ray reflected at the upper conducting layer of the atmosphere will have a component polarised in the horizontal plane.

If the aerial is symmetrical about a vertical axis as, for instance, an umbrella type aerial, then the ray will be polarised entirely in the vertical plane (z, x, β) and therefore cannot produce any E.M.F. in the loop when this is perpendicular to the line joining it to the transmitter.

If, however, the reflecting layer is not horizontal (Fig. 8), reflection will introduce a component polarised in the horizontal plane.

Again if the conducting layer is æolotropic, an effect which might be produced by the earth's magnetic field making the conductivity different in different directions, or if there is a rotation of the plane of polarisation due to the presence of electrons in this field, this will result in the production of a reflected ray polarised in the horizontal plane even when the transmitter is symmetrical and the reflecting layer is sensibly level.

It will be seen that there are two different ways in which the bad night bearings may be produced :—

(1) An effect due to asymmetry of transmitting aerial.

(2) An effect due to the asymmetry of the Heaviside layer, due to its being tilted to one side or the other, or to its conductivity being different in different directions.

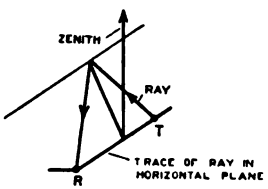

FIG. 8.

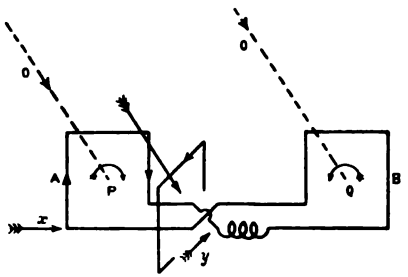

FIG. 9.

These effects may be separated by using a receiver of the following kind. A receiver is used in which each of the ordinary closed loops of the Bellini-Tosi aerial is replaced by two loops (in the same plane) connected up so that the E.M.F.'s induced in the two aerials are nearly in opposition (see Fig. 9). In this case it is obvious that a wave travelling in the plane of AB (in the x direction) will only produce an E.M.F. in the complete system on account of the difference in phase of the E.M.F. induced in A and B. A wave travelling in the yz plane will produce no E.M.F., even when the ray is tilted (as in Fig. 9) for in this case the flux linkage with each loop A and B is the same,

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and in the same phase. This system will therefore eliminate the effect o the ray reflected in the vertical plane (so long as this ray is entirely in the vertical plane). If, on account of reflection from a tilted reflecting layer, the ray no longer remains in the vertical plane, the length of the path of the ray OP to the frame A differs from the length of path of the ray OQ to the frame B, so that the E.M.F.'s induced at A and B will not be in phase, and a resulting E.M.F. will ensue, and the system will no longer give true bearings.

The intensity of the ray reflected in the vertical plane may seem at first sight to be rather too large, but it must be remembered that this indirect ray is not subject to the same attenuation as the direct ray, which may be intercepted by mountains or reduced by losses in travelling over the earth. In this connection the effect of mountains in reducing the direct ray in comparison with the indirect ray, and thereby increasing their errors, is particularly marked, and it is almost impossible to get good bearings in mountainous countries at night.

Another experiment to prove the existence of the indirect ray was carried out as follows (Fig. 10).

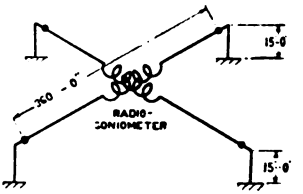

FIG. 10.

These were made with a direction finding apparatus consisting of two horizontal aerials in the place of the vertical loops. The two aerials were perpendicular and were at a level of about 15 feet above the ground, and had a span of about 120 yards. The bearings were compared with those taken on an ordinary Bellini-Tosi aerial. The receiving system was situated at Salonika and the transmitting station chosen for these experiments was the large power station at Constantinople. The mean day bearing of this station was 83° (which differs only a fraction of a degree from the true bearing). The night bearings are rather variable, but have a mean of about 89° or 90°; thus there is a systematic error of 6° or 7°. When receiving on the horizontal aerials at night the bearings of Constantinople were about 62°. Accurate check bearings were taken on other neighbouring stations at the same time so that the error was not due to instrumental faults.

We may at once infer from the bearing obtained that there must be a component of the electric force horizontal and perpendicular to the plane of propagation. This horizontal force is in the opposite sense to that which might at first sight have been expected, for it reduces the bearing instead of increasing it (as on the Bellini-Tosi aerials), but this fact is in accordance with the theory, for it can be shown by a rough calculation that the two systems of aerials, *i.e.*, the horizontal aerial and the Bellini-Tosi aerials, should give deviations in opposite directions.

This calculation can be made as follows :—

As before we will assume that the waves are approximately plane. The electric forces which are concerned in producing currents in the horizontal aerial are the following :—

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(1) The horizontal electric force in the direct ray.

This will be in the plane of propagation and its intensity (compared with the vertical force in the same ray) will depend chiefly on the conductivity of the ground over which the ray passes according to the theories of Zenneck and Sommerfeld.

(2) The horizontal electric force in the ray reflected at the upper conducting layer perpendicular to the plane of propagation.

(3) The horizontal electric force in the reflected ray in the plane of propagation.

The second is the one which produces the deviation from the true bearing.

In order to get the mean value of the effect of (2) we will neglect the effect of (3). (1) and (3) may be opposed and give prominence to (2).

As before let the X axis, be the direction in which the waves are advancing, the plane $Z = 0$ the surface of the earth, then the electric force we are concerned with, and which produces the errors, is parallel to the Y axis. The electric forces in the *direct* wave are in the X and Z directions and may be expressed in the form :—

$$\left.\begin{aligned} X &= X_0 \epsilon^{j\nu nz} \epsilon^{j\nu(lx - ct)} \\ Y &= Y_0 \epsilon^{j\nu nz} \epsilon^{j\nu(lx - ct)} \\ \beta &= \beta_0 \epsilon^{j\nu nz} \epsilon^{j\nu(lx - ct)} \end{aligned}\right\} \text{ above the earth's surface. . . . (23)}$$

$$\left.\begin{aligned} X &= X_0' \epsilon^{j\nu n'z} \epsilon^{j\nu(lx - ct)} \\ Y &= Y_0' \epsilon^{j\nu n'z} \epsilon^{j\nu(lx - ct)} \\ \beta &= \beta_0' \epsilon^{j\nu n'z} \epsilon^{j\nu(lx - ct)} \end{aligned}\right\} \text{ below the earth's surface . . . (24)}$$

Where $\nu = \frac{2\pi}{\lambda}$, λ is the wavelength, and c = the velocity of light. l, n, n' are so chosen as to satisfy the differential equations and the surface conditions.

The components of the incident and reflected waves have already been expressed in equations (3).

When using the horizontal aerials the angular deviation θ_1 from the true bearing is measured by the ratio of the total electric force in the y direction to that in the x direction, *i.e.*,

$$\tan \theta_1 = \frac{Y_0 + Y_r}{X_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

when the forces in the x and y directions are in phase.

In this experiment good minima were obtained so that we can infer that this last condition was satisfied.

The E.M.F.'s induced in the closed loops when their maximum linear dimensions are small compared with the wavelength are—

(1) $A\left(\frac{\partial Z}{\partial x} - \frac{\partial X}{\partial z}\right)$ in the xz loop . . . . . (26)

and (2) $A\frac{\partial Y}{\partial z}$ in the yz loop . . . . (27)

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so that the angle of deviation θ_2 is given by—

$$\tan \theta_2 = \frac{\frac{\partial Y}{\partial z}}{\left(\frac{\partial Z}{\partial x} - \frac{\partial X}{\partial z}\right)} \quad \ldots\ldots\ldots \quad (28)$$

Now the X and Z forces are in the direct ray transmitted over the surface of the earth.

We can therefore apply Zenneck's analysis of the propagation of plane waves over a semi-conducting medium.

It is not difficult to show that

$$\left(\frac{\partial Z}{\partial x} - \frac{\partial X}{\partial z}\right) = j\nu l\left\{\left(M + \frac{1}{M}\right)\cos\phi - j\left(M - \frac{1}{M}\right)\sin\phi\right\} \quad \ldots \quad (29)$$

where

$$M = \left(\frac{n'}{l}\right) = +\sqrt{\frac{m}{\sqrt{1+m'^2}}} \quad \ldots\ldots \quad \text{(in which the positive square root must be taken)}$$

where

$$m = \frac{\nu K}{\sigma} \quad m' = \frac{\nu K'}{\sigma}, \tan 2\phi = \frac{1}{m'}$$

σ is the conductivity of the ground.

K is the specific inductive capacity of the air.

K' is the specific inductive capacity of the earth.

νl to the accuracy we require is $\frac{2\pi}{\lambda}$ where λ is the wavelength.

Now Y is the component of the electric force in the reflected ray, and we can derive from equations

$$i.e., \begin{cases} \frac{\partial Y}{\partial z} = j\nu n(Y_0 - Y_r)\epsilon^{j\nu(lx - ct)} \text{ (at the surface of the earth)} \\ \frac{\partial Y}{\partial z} = \frac{2\pi jn}{\lambda}(Y_0 - Y_r)\epsilon^{j\nu(lx - ct)} \text{ from (3)} \end{cases} \quad \ldots \quad (30)$$

now

$$\frac{n(Y_0 - Y_r)}{(Y_0 + Y_r)} = \frac{S}{\mu'} + \frac{jS'}{\mu'} \quad \ldots\ldots\ldots \quad (31)$$

where S and S' have the same significance as in equations (4), (5) and (6), so that

$$\tan \theta_2 = \frac{\frac{2\pi j}{\lambda}\left(\frac{S}{\mu'} + \frac{jS'}{\mu'}\right)(Y_0 + Y_r)}{\frac{2\pi j}{\lambda}(X_0)\left\{\left(M + \frac{1}{M}\right)\cos\phi - j\left(M - \frac{1}{M}\right)\sin\phi\right\}} \quad \ldots \quad (32)$$

and $$\tan \theta_1 = \frac{Y_0 + Y_r}{X_0} \quad \ldots\ldots\ldots\ldots\ldots \quad (33)$$

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$$\text{so that } \tan\theta_2 = \frac{\left(\frac{S'}{\mu'} + \frac{jS'}{\mu'}\right)}{\left\{\left(M + \frac{1}{M}\right)\cos\phi - j\left(M - \frac{1}{M}\right)\sin\phi\right\}} \times \tan\theta_1 \quad . \quad (34)$$

Now in practically every case M is a small quantity, ϕ is nearly 45°, and S approximately equal to S'

$$\text{so that} \qquad \tan\theta_2 = \frac{\frac{S}{\mu'}}{\frac{1}{\sqrt{2}M}} \times \tan\theta_1 = \frac{MS\sqrt{2}}{\mu'} \times \tan\theta_1 \quad . \quad . \quad . \quad . \quad (35)$$

where M is a positive quantity and S a negative quantity. θ_2 is therefore of the opposite sign to θ. That is the error when using the horizontal aerial is the opposite sign to that found when using the vertical aerials.

Unfortunately it is not possible to make any accurate numerical calculations, as these involve the electrical constants of the ground in the neighbourhood of the receiving station which have not been measured.

The following calculations based on rough values of similar ground show the approximate magnitude of the deviation to be expected. These do not vary much with the constants.

Take for example :—

$K = 2.$ $\quad N = 0{\cdot}133.$ $\quad \rho = 10^{15}.$ $\quad$ Frequency $= 2 \times 10^5$, where ρ = resistivity in C.G.S. units.

then $\quad S = -2{\cdot}24, \quad \frac{1}{m} = 4{\cdot}5, \quad \tan 2\phi = 4{\cdot}3$

$S' = -2{\cdot}00, \quad \frac{1}{m} = 9, \quad \phi = 38° 45'$

$\cos\phi = 0{\cdot}780 \quad M = 0{\cdot}328 \quad \left(M + \frac{1}{M}\right)\cos\phi = 2{\cdot}6$

$\sin\phi = 0{\cdot}626 \quad \left(M - \frac{1}{M}\right)\sin\phi = -16{\cdot}4$

$$\text{so that} \qquad \tan\theta_2 = -\tan\theta_1 \cdot \frac{2{\cdot}24 + j\,2{\cdot}00}{2{\cdot}60 + j\,1{\cdot}64}$$

$$\text{or} \qquad \tan\theta_2 = -0{\cdot}975\epsilon^{-j\phi_1}\tan\theta_1.$$

$$\text{where} \qquad \phi_1 = 9° 25'$$

roughly neglecting the difference in phase $\theta_2 = -\theta_1$ nearly,

or again take $\quad K' = 2, \quad \rho = 10^{14} \quad n$ small $\quad$ Frequency $= 2 \times 10^5$

then $\quad S = S' = 6{\cdot}7, \quad 2\phi = 90°$ very nearly

$$\sin\phi = \cos\phi = \frac{1}{\sqrt{2}}, \quad M = \frac{1}{13{\cdot}4} = 0{\cdot}074,$$

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in which case $\tan \theta_2 = -\tan \theta_1 \dfrac{6{\cdot}7 + j\,6{\cdot}7}{9{\cdot}55 + j\,9{\cdot}50} = -\dfrac{6{\cdot}7}{9{\cdot}5} \tan \theta_1$

$$= -0{\cdot}255$$

$$\theta_2 = 14^\circ\ 20'$$

taking the observed value 21° $(= 83 - 62)$ for θ_1.

In both cases the calculated value of θ_2 is too big. An agreement of the right order is obtained and there is very little room for doubt that the explanation offered is approximately correct.

Reflection and Refraction in a Stratified Medium.

The observed fluctuations in bearings can be accounted for by assuming that the transition layer, where the conductivity increases, is much narrower and more sharply defined at night than in the daytime, and that, in fact, in the latter case the ionisation extends practically down to the ground, while in the former case the lower boundary of the ionised layer is more or less sharply defined. If this is so transmission will be more or less normal in the daytime, and the energy will decrease partly on account of the spreading out of the waves, partly according to the diffraction of waves round the earth and partly on account of absorption in the earth and ionised air.

At night time longer distances will be traversed because the energy is more or less confined to the annular space between two conducting spheres.

This agrees with Dr. Fleming's conclusions on transmission over long distances, and he bases his ideas on a similar theory, *i.e.*, Dr. Eccles' theory of ionic refraction.*

Dr. Eccles has shown that the presence of heavy ions in the air increases the velocity of propagation so that in a medium in which the ionisation increases with the height, the ray leaving the earth will tend to curve downwards and be refracted to the earth again. The curvature depends on the rate at which the velocity of the wave increases with the height, *i.e.*, upon the rate of change of conductivity with the height, if this latter quantity becomes very great this refraction is practically indistinguishable from reflection. The theory in this form is just what is required to explain the fluctuations in bearings at night if it is assumed as well that the transition layer is narrow at night and broad in the daytime.

The theory as given by Eccles is, however, hardly complete as it is not given as a solution of the differential equation of propagation in a medium of varying ionisation. In fact in calculating the path of the ray the effect of absorption is neglected. For this reason I have attempted to solve the particular case in which the conductivity varies in proportion to the height above a given datum.

The work is based on Dr. Eccles' theory of ionic refraction and the same assumptions as regards ionisation are involved. There appears at first sight to be a grave objection to this theory in any form, for it seems to

* J. A. Fleming. *Principles of Electric Wave Telegraphy.* Third edition, p. 842.

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involve the possibility of waves being propagated with a velocity greater than that of light. Now this theory is based on Maxwell's equations which are the appropriate expressions of a system in which effect can only be propagated with velocities equal or less than that of light; so that there seems to be a logical contradiction involved.

This contradiction is removed when we observe that according to Eccles' theory the velocity of propagation depends upon the wavelength so that the group velocity and phase velocity are different, and it can be shown that the group velocity which is really the velocity of propagation, is less than that of light.

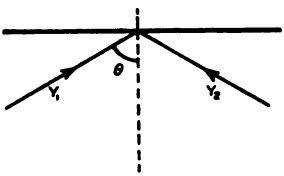

FIG. 11.

I have investigated the case where the conductivity below a certain height is zero, and above that height varies in proportion to any increase in height. It can be shown then that if Y_2/Y_1 is the ratio of the reflected to the incident ray at this surface (Fig. 11), then

$$\frac{Y_2}{Y_1} = \frac{he^2}{8n\,(\nu^2 n^2)\,(m^2 p^2 + f^2)} \cdot \quad \ldots \quad (36)$$

where h = the rate of increase of the conductivity with the height.
e = the charge on the ion or electron.
m = the mass of the ion or electron.
p = $2\pi \times$ frequency of the waves.
f = the frictional force to which an ion or electron is subject when moving with a uniform velocity v, according to which $v = \frac{Xe}{f}$, where X is the electric force on the charge e.
ν = $2\pi/\lambda$, λ is the wavelength,
and n = $\cos\theta$, where θ is the angle the ray makes with the vertical.

We see at once from this solution that when $\frac{Y_2}{Y_1}$ is small the reflected wave Y_2 is proportional to h the rate of increase of the conductivity with the height, *i.e.*, upon the sharpness of the transition, which confirms the statements already made.

Numerical Results.

The quantity

$$\frac{he^2}{8(\nu n)^2 n\sqrt{m^2 p^2 + f^2}}$$

which is the ratio of the reflected to incident wave must be of the dimensions of a number. The equations have been expressed in terms of the Heaviside system of units, so that if we use electromagnetic units the quantity

$$\frac{he^2}{8(\nu n)^2 n\sqrt{m^2 p^2 + f^2}}$$

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must be altered to

$$\frac{he^2c}{8(\nu n)^2 n\sqrt{m^2p^2+f^2}} = h\cdot\frac{e}{m}\left(\frac{ec}{\nu^2n^3\sqrt{p^2+f^2/m^2}}\right) \quad . \quad . \quad . \quad (37)$$

First Case, where the mass of the ions is so small that p^2m^2 can be neglected in comparison with f^2.
The quantity becomes

$$\frac{he^2c}{8n^3\nu^2 f} = \frac{e^2cN_1}{8n^3\nu^2 f_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (38)$$

if N_1 is the number of ions at 1 km height, and f_1 the value of f at this height.
Now the specific conductivity is $\frac{N_1e^2}{f_1} = \sigma_1$ say . . . . . (39)

$$\therefore \frac{\sigma_1 c}{8n^3\nu^2\times 10^5} = \text{ratio of reflected to incident wave} \quad . \quad . \quad . \quad . \quad (40)$$

If we assume that this ratio has a value of 10 per cent. say, then we shall have an equation for σ_1

$$\sigma_1 = \frac{1}{10}\cdot\frac{8n^3\nu^2\times 10^5}{c} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (41)$$

Take $\lambda = 600$ metres say—
(1) Take $n = 0{\cdot}1$

then $$\sigma_1 = \frac{8\times 10^{-3}\left(\frac{2\pi}{600}\right)^2\times 10^{-8}\times 10^5}{10\times 3\times 10^{10}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (42)$$

which is of the order of $\frac{10^{-16}}{3}$.

(2) Take $n = 0{\cdot}5$

σ_1 is of the order $\frac{1}{6}\times 10^{-13}$ absolute units

which is of the same order as the conductivity of dry earth and seems a quite reasonable value to assume.

Schuster has shown that it is necessary to assume a mean conductivity of this order to account for the diurnal changes of the magnetic elements in his theory.

Accuracy of this Estimation.

The accuracy of the asymptotic solution we have used is of the order of the last term used in the series.
This term is

$$T = \left|\frac{1\times 5}{4^2\times 3}\cdot\times\frac{\phi}{(z_1)^{\frac{3}{2}}}\right|_{z=0} = \left|\frac{5}{48}\cdot\frac{\phi}{r^3}\right| \quad . \quad . \quad . \quad . \quad . \quad (43)$$

now $$r = \nu^2(1-l^2) = \nu^2n^2$$

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so that $$T = \left| \frac{5}{48} \cdot \frac{\phi}{\nu^3 n^3} \right| = 0{\cdot}104 \frac{\phi}{\nu^3 n^3} \quad . \quad . \quad . \quad . \quad . \quad . \quad (44)$$

but $\frac{Y_2}{Y_1} = 0{\cdot}125 \frac{\phi}{\nu^3 n^3}$ so that the accuracy of estimation of Y_2/Y_1 is practically equal to its magnitude, in the case we have assumed 10 per cent.

Second Case.—mp and f comparable.

The quantity $\frac{N_1 e^2}{f_1}$ is still the mean conductivity for steady electric forces, but instead of $\frac{he^2c}{8\nu^2 n^3 f}$

we have $$\frac{he^2c}{8\nu^2 n^3 f (1 + m^2p^2/\alpha^2)^{\frac{1}{2}}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (45)$$

i.e., $$\frac{\sigma_1 c}{\nu^2 n^3 \times 10^5} \frac{1}{(1 + \alpha^2)^{\frac{1}{2}}}, \text{ say}$$

and the values of σ_1 before obtained have to be multiplied by the factor $(1 + \alpha^2)^{\frac{1}{2}}$ which is large compared with unity when mp is large compared with f.

In the calculation of σ we have assumed that f is large compared with mp. We can get an estimate of the lower limit of the ratio $\frac{f}{mp}$ by assuming the ions or electrons have their maximum mobility at the specified pressure. Kaye and Laby give the maximum mobility of the negative ion produced by X-rays as 1·7 (cm) × (sec.)$^{-1}$ (volts)$^{-1}$ at normal pressures and temperatures. The mobility at low pressures should increase inversely as the pressure

$$K_p = 1{\cdot}7 \times \frac{P_0}{P} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (46)$$

$$K_{p(\text{abs.})} = 1{\cdot}7 \cdot \frac{P_0}{P} \times 10^{-8}$$

now under a steady electric force

$$fv = Xe \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (47)$$

or $$f = \frac{Xe}{v} = \frac{10^8}{1{\cdot}7 \frac{P_0}{P}} \cdot e$$

and $$\frac{f}{mp} = \frac{10^8}{1{\cdot}7 \cdot p} \frac{e}{m} \cdot \frac{P}{P_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (48)$$

taking $$p = 3 \times 10^6$$

$$\frac{f}{mp} = \frac{3{\cdot}4 \times 10^8 P}{P_0} \text{ about} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (49)$$

and this is a large quantity so long as $\frac{P}{P_0}$ is not less than $\frac{1}{10^6}$ say.

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At the height of about 100 km $\frac{P}{P_0}$ is of the order of 5×10^5, and for hydrogen and the lighter gases it is even greater than this, so that the condition $\frac{P}{P_0} \ll 10^{-6}$ seems to be satisfied under all normal conditions at this height. If the pressure P were so small that the interval between encounters of electrons and molecules was large compared with the period of the waves then the absorption of energy, of which f is the measure, is due to the acceleration of the electrons produced by the electric forces in the wave.

SUMMARY

If the experiments in this paper are considered to be valid then the existence of a ray reflected at night time from some upper conducting layer of the atmosphere may be considered to be beyond doubt, and the fact that this ray is responsible for part of the errors in night bearings may also be taken as proved. But a doubt still exists if this is the only way in which errors are produced, and it is still uncertain whether the errors are due to a ray reflected in a purely vertical plane from a perfectly horizontal conducting layer, or by reflection from a partially tilted layer. Probably both these causes of error exist.

Experiments as described on p. 239 should determine this point.

The manner in which the ray is reflected is suggested in the later, more speculative, part of the paper and it seems that a possible explanation is offered, and that the numerical values of the conductivity and rate of increase of conductivity with height required by the theory are not impossible.

Many points in connection with this subject have not been touched upon for instance the apparent systematic swinging of bearings at sunset, and the variation of bearings taken on radiophare stations as the transmitter rotates, as observed by Captain Tremellen, and his results on the sunset variations of the strength of signals from Clifden all of which might probably be explained on the reflection theory, but the satisfactory result remains that a reasonable explanation of night effects has been offered and confirmed by experimental results.

Some Acoustical Effects in Wireless.—A paper with this title was read by Capt. J. Robinson, M.Sc., Ph.D., at a meeting of the Wireless Society of London on April 4th, 1921. The author pointed out the importance of acoustical effects in wireless, and then discussed the heterodyne effect and the lag of the ear as a function of the pitch of the note. When transmission is rapid, dots may be missed if the heterodyne beat note is made too high. The variation of the oscillation frequency of a valve with the potential of the anode battery was dealt with, as well as the production of notes by a high-frequency oscillating valve making use of a grid leak and condenser, and the factors governing the pitch of this note were discussed. The application of this arrangement (termed by Major Prince a "squegger") to a receiver in which the pitch of the note heard in the telephones is a function of the strength of the signal, was also described.

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A New Radiomegaphone.

Considerable interest has been aroused recently in the claims made for a new receiving apparatus that has been installed in the electrical engineering laboratories of the College of the City of New York of which Dr. G. N. Goldsmith, the secretary of the Institute of Radio Engineers, is director. The development of the receiver to its present pitch of perfection has been the result of many years of research work. It involves the use of no essentially new discovery but the good results obtained are due to gradual development and improvement of the component parts of the amplifier. Ten three-

electrode valves are employed in conjunction with a loud speaking telephone. The wavelength tuning range of the set includes 600 metres as well as the long wavelengths used for transatlantic signalling, and it is claimed that the signals obtained from Nauen (Germany) are almost uncomfortably loud all over the laboratory. Claims made for the instrument are great selectivity in tuning, and distortionless amplification. From the attached illustration it may be noted that the last valves of the set are of a much larger size to permit of the handling of more energy for operating the loud speaking telephone.

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Nauen and Togoland: A Tragedy of Radio-Telegraphic Development.

By Dr. R. ROSCHER.

(*Concluded from page 75 February issue.*)

THE CONSTRUCTION OF THE LARGE WIRELESS STATION KAMINA (TOGO). THE PERMISSION TO CONSTRUCT LARGE WIRELESS STATIONS IN THE GERMAN PROTECTORATES IN AFRICA.

While it was still an open question whether the contemplated large wireless station uniting the African colonies with the mother country should be built in Togo or Kamerun, there was much to be said in favour of Kamerun. It was the larger and more important of the two Protectorates, and the defence of the station could there be assured, whilst this was not possible in the narrow Protectorate of Togo, enclosed by French and English territory, and insecure against possible surprises, owing to the small military forces at its disposal. On the other hand, difficulties of transporting apparatus and machines, difficulties of telegraphic connection with the coast, stood in the way of finding a suitable location in Kamerun. After the favourable results of the preliminary tests in Togo it was therefore resolved not to wait for the results of further experiments, but to construct at once a fully equipped large wireless station in Togo in order to establish connection as soon as possible. Kamerun would in any case, through the coast wireless station Duala, be joined up with the colonial wireless network *via* the Togo wireless station.

Although the capital required, and consequently the economic risk, is considerably less for wireless telegraphy plant than for cables, it was nevertheless decided not to charge the construction of either the large wireless stations or the coast stations in Africa directly to the imperial budget. The problem to be solved in such constructions required a large amount of special experience. In view of the peculiar nature of wireless telegraphy, unexpected difficulties in the technical details of construction or operation might occur, difficulties which a private undertaking, free to move in any direction and having at its disposal a staff of trained engineers, could more easily overcome than the Imperial Government, which did not possess any body of men trained in the building and operation of large wireless telegraphy establishments situated in oversea territories. The private concern coming naturally first in question was the Telefunken Company. The chief considerations in its favour were (1) that it had established itself firmly in all parts of the world, (2) that it had already built a large number of wireless stations abroad, and, in particular, the establishments in the German Protectorates, (3) that in doing so, as well as in carrying out the range tests and the preliminary experiments for bridging the distance between Germany and Central Africa, it had gathered valuable experience which would be immediately useful for the present purpose, (4) that hitherto no other company had either guaranteed or effected such a connection.

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In view of these considerations and of the successful issue of the preliminary tests, the Company on June 12th, 1913, was granted permission to construct one direct radio-telegraphic connection between Germany and Togo and one between Togo and German South West Africa and to work them for a period of twenty years reckoned from the day on which the operation of the connection should definitely begin. The permission was granted subject to the following conditions :—

The Company guarantees, at its own cost—

(*a*) To erect at Atakpame in Kamina (Togo) and to operate for twenty years a wireless station capable of communicating with the station at Nauen as well as with a station in German South West Africa and a projected station in German East Africa.

(*b*) To enlarge and improve its station at Nauen so that mutual communication should be possible between that station and the station in Togo.

(*c*) To erect and operate for a period of twenty years a station at Windhoek (German South West Africa) capable of communicating with the establishment in Togo and with the station projected for East Africa.

At the demand of the Imperial Government, the wireless stations named in (*a*), (*b*) and (*c*) were to communicate with other German and foreign stations as far as communication was possible. In a general way, daily communication to and fro between the stations in Togo and Nauen for four hours was to be possible with a minimum speed of seventy-five letters per minute. If on individual days, in consequence of atmospheric disturbances in Togo, this minimum could not be attained, it was stipulated that within any five consecutive days at least 1,200 paid words of ten letters should be transmitted in each direction. For the connection Togo—South West Africa an assured daily communication of at least four hours with a minimum speed of seventy-five letters should be practicable. If, in consequence of atmospheric disturbances, communication were interrupted for more protracted periods, the imperial subsidy was to be reduced. This subsidy was to be 592,000 marks for the Togo station, and 454,000 marks for the station in South West Africa ; it was to take effect from the day on which the operation of the stations definitely commenced and should continue for a period of twenty years. The definitive operation of the Togo—Nauen connection should begin when, during the test operations, the prescribed minimum had been reached for at least thirty days. The operation of the Togo—South West Africa connection should definitively begin when, on eight consecutive days, 400 words of ten letters could be transmitted daily with a speed of seventy-five letters per minute. The Imperial Government reserved to itself the right of purchasing at any time the wireless stations in Togo and South West Africa. The Imperial Government was to pay to the W.T.C. a yearly sum of 111,500 marks for placing its Nauen station at the disposal of the Government for communication between Germany and Togo, and for operating this station with its own employees. There was conceded to the Imperial Government the

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option of purchasing the station at Nauen, which station might be acquired at any time. The Imperial Government was to receive for the use of its wires the usual fees paid for telegrams proceeding from or going to Germany and her interior, or the German Protectorates and their interior, when these telegrams had to traverse the wireless telegraphic routes for which this present permission was granted ; it was also to receive 75 per cent. of the fees payable for the transmission of telegrams over these wireless routes. The Imperial Government was empowered at any time temporarily to operate the station by its own officials. The operation of these wireless routes should be regulated by the International Telegraph Convention, the International Wireless Telegraph Convention, the various agreements for applying these Conventions and the special imperial decrees for the radio-telegraphic service. The determination of fees, the conclusion of agreements with other telegraph administrations concerning the transmission of telegrams, as well as the conclusion of all agreements with other governments were subject to the

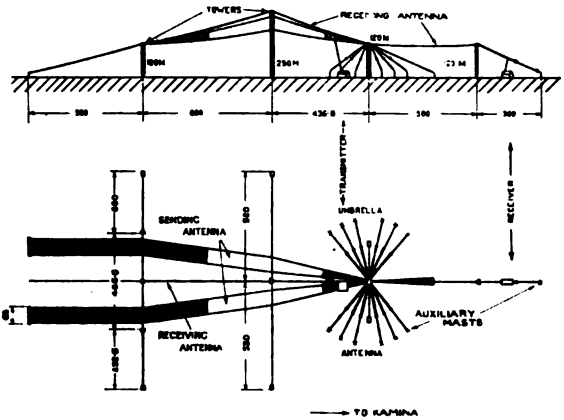

FIG. 2.

approval of the Imperial Government. The fees for telegrams sent or received by the German Government should be reduced by 50 per cent. The W.T.C. was bound, at the demand of the Imperial Government, to construct in German East Africa during the financial year 1914 the proposed large wireless station to communicate with the wireless stations in Togo and South West Africa. Whether the station in East Africa had to fulfil further tasks was reserved for the decision of the Imperial Government. A subsidy was also to be paid to the Company for the construction and operation of this latter station. The Imperial Government might cause experiments to be undertaken by the W.T.C. in order to ascertain whether direct communication was possible between Nauen on the one hand and the large wireless stations in South West Africa and East Africa on the other, or by what means such communication could be attained. Authorisation was given to the Imperial Post Office to acquaint itself at any time with the circumstances of the undertaking for which the present authorisation was granted.

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It was laid down by a special agreement that the W.T.C. should possess no monopoly of radio-telegraphic transmission of telegrams between Germany and the African Protectorates or between the latter themselves. In respect of the experimental operation of the stations, it was agreed that this was to show whether the individual parts, separately as well as collectively, were able to meet all requirements even when working at high pressure, what wavelengths were best suited for operation by day and by night, and how the hours for operation could best be chosen.

The plant at Nauen had to be increased as follows for the communication with Africa. A quenched spark transmitter of 100 kW antenna power was installed. A main tower 252 m in height, and five towers each 120 m in height, were to support the antenna. The transmitting antenna was to consist of twenty stranded bronze wires 800 m long and 4 mm in diameter. The receiving antenna of two stranded bronze wires 1,700 m long and 9 mm in diameter. The arrangement can be seen from Fig. 2.

THE DESCRIPTION OF THE LARGE WIRELESS STATION AT KAMINA.

The large wireless station in Togo, for which the situation decided upon was that used for the experiments, at Otakpame in Kamina, was arranged for an antenna power of about 100 kW; for the connection between this station and the coast establishment in Lome, supplementary apparatus of 2·5 kW antenna power was contemplated. Three iron frame masts, each 75 m in height, and six, each 120 m in height served to support the antennæ; of the latter masts, four were surmounted by extensions 7 m in height for the receiving antenna. The transmitting antenna consisted of twenty stranded bronze wires (5 mm in diameter) 600 m in length, the receiving antenna, of a brass rope (12 mm) 3,350 m in length, the earthing system of thirty copper plates, the insulated counter capacity of twenty copper wires (2·5 mm) and about 1,600 m in length. Besides that, a small transmitting-receiving antenna was provided for the supplementary wireless station.

To the power station belonged :—

(*a*) The boiler house with three tube boilers (one of them as reserve) arranged for wobd firing. The wood was to be obtained from an afforestation situated in the Protectorate. Even during the war, firing was done with wood obtained in the neighbourhood. This mode of working proved quite satisfactory. The boiler house was equipped with all essential accessories, *e.g.*, water and steam gauge, water purifier, ring steam main, economiser and forced draught. For the cooling of the condensed steam there was a huge cooling apparatus 30 m high.

(*b*) The turbine and steam engine establishment consisting of two steam turbines of 500 H.P. and two vertical steam engines of 120 H.P. (one of each as reserve ; in fact all parts of the power station were duplicated).

(*c*) The main power plant with the following parts :—

(α) Two alternating-current generators, each of about 350 kW (one of them as reserve), directly coupled with a steam turbine.

(β) Two continuous current machines each of 75 kW and 220—250 volts (one as reserve) directly coupled each with one of the 120 H.P.

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steam engines, for exciting the alternating current generator, charging the storage battery, driving the air pumps.

(γ) One strong battery with 131 cells, 259 ampere hours at the one hour discharge rate.

(δ) One Booster set consisting of continuous current motor and supplementary dynamo of about 15 kW, 20—30 volts.

(ε) One continuous current—alternating current transformer of 10 kW (for the auxiliary transmitter).

The transmitting plant consisted of the main transmitter (100 kW oscillating power in the antenna for waves of 3,500, 4,200, 5,500, 7,500, and 9,500 m) and the auxiliary transmitter. The receiving equipment consisted of three telephonic receiver sets with a continuous wave range of 200 to 14,000 m for the large wireless plant, and 300 to 2,500 m for the supplementary one.

The buildings of the wireless station included the transmitting house, consisting of boiler house, engine house, high frequency room, battery room, firewood sheds, workshop, storeroom, the dwelling house for the manager, the receiving house, a dwelling house for the telegraphists, as well as one for the machinists.

A light railway more than 5 km in length was built connecting the village Agbonu, a station on the Togo hinterland railway, with the wireless station, in order to convey the iron parts for the supports of the antennæ, the machines, etc. At the railway station of Agbonu stood a crane spanning the tracks of the Togo railway and the light railway and permitting the direct transference of goods from the one to the other. The light railway led through the bush to Kamina alongside the road constructed by the Company. A branch line connected the wireless station with the place whence was obtained the sand serving for the manufacture of cement and tiles, which were always used for the permanent houses. On the building plot were three deep wells from which water was raised by means of electric centrifugal pumps into a reservoir 10 m high. From the reservoir the water flowed to the various points where it was required, the boiler house, the dwelling house, the brick field, the washhouses, etc. The brick field was near the reservoir.

The enormous plot, covering an area of four square km, and traversed by a light railway of 4 km in length and by roads 8 km long, had been conceded free of charge by the administration of the Protectorate. Difficulties of various kinds had prevented the work of construction from running smoothly: a fire broke out, and building material was lost in the surf at Lome in an attempt to extinguish it, etc. A trial operation of the station was to precede its definite opening. This trial was begun on June 20th, 1914, but was discontinued owing to the outbreak of war.

THE LARGE WIRELESS STATION KAMINA DURING THE WAR. ITS ACHIEVEMENTS.

The war, which put a stop to the creation of a German network of wireless stations, afforded an opportunity of showing whether the Kamina station was capable of standing so severe a test. That it did in the fullest measure.

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Shortly after England had declared war, and after a proposal to remain neutral, made by the Governor of the Protectorate Togo, had been rejected by the Governor of the English Gold Coast Colony, two English messengers arrived to negotiate with the Governor the surrender of Lome and a part of the Protectorate. The Governor of Togo found himself obliged to give up Lome and ordered that the place should be surrendered to the English on the following day, whilst those Europeans who were capable of military service should proceed with the police force under his command to Kamina, in order to defend the wireless station there; such being the instructions of the Imperial Colonial Office. On the evacuation of Lome and the hinterland, during the night of August 6th and 7th, 1914, the coast wireless station at Lome was destroyed to such an extent that its restoration was made exceedingly difficult, if not impossible. The tower of the station was overthrown.

The large wireless station Kamina rendered extremely valuable service, although the preliminary tests were not yet ended, and although the establishment had not yet been taken over and did not yet possess all the equipment destined for it. At first the station was kept ready at any time to receive from and transmit to the counter establishment at Nauen. Later on, such hours were fixed for receiving from and transmitting to the stations at Nauen, Windhoek, Duala, as were found most favourable for the respective stations. In communicating with Windhoek and Nauen, the wavelength used by day was 6,000 m and by night 4,500 m. Duala transmitted by day with a wavelength of 2,500 m and by night, 1,600 m, Kamina always with the 4,300 m wave. Especially important was the connection Kamina-Duala after the destruction of the coast wireless station at Lome.

The warning issued to the merchant ships lying within the range of Kamina, and the summons to put into neutral harbours produced good results; it is well known that but few ships fell into the enemy's hands. Statistics drawn up after an inquiry made by the Scientific Committee of the Prussian Ministry for War show that the warning signals sent by German wireless stations saved the country 800,000 tons of shipping. The Hamburg-America line stated that forty-seven steamers of 287,237 gross tonnage had been saved by wireless telegraphy and estimates the value of these steamers at 93·3 million marks. The overseas German stations, in particular the large establishments at Kamina and Windhoek, contributed largely to this work of rescue.

What imparted greatest value to the Kamina wireless station was the fact that after the German cable had been cut, the mother country still possessed independent means of maintaining the important connection with her West African colonies. Even telegrams from Western Europe to Berlin which had failed to reach their destination owing to the cutting of European connections, were sent by the circuitous route *via* Spain-Teneriffe-Monrovia-Lome (by the cable of the German South American Telegraph Company) and thence by radiogram *viâ* Kamina to Nauen. By agreement with the cable station Pernambuco, a considerable portion of the communication it normally carried on between South America and Germany was deflected *viâ* Lome—

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Kamina; this intercourse would otherwise have been either impossible or subject to very great delay, after the cutting of the German cable on August 5th, 1914; since the foreign routes which might be used as substitutes were so fully occupied. It was only ascertained later that a unidirectional connection Kamina—German East Africa had been achieved. News from Kamina, including important official telegrams, was received by an establishment constructed out of equipment taken from wireless stations on board ships and from the demolished station at Dar es Salem. For the sake of additional security Windhoek was likewise requested to transmit the telegrams for German East Africa. From the military and political point of view as well, a constant connection with Berlin and the transmission of official news to Duala and Windhoek was a great advantage. The direction Kamina—Duala worked well, and thus the fears previously mentioned proved groundless. Also all telegrams from Duala to Kamina could be received and forwarded to their destination, but often with considerable delays, and at times the signals were very weak or failed to arrive altogether. The cause of this lay in the heavy load on the sole storage battery (there was no reserve battery) in consequence of the very frequent war communication with Fernando Po, the steamer *Kamerun* lying at the entrance to the harbour of Duala, the coast wireless station Lome and the large wireless station Kamina. When messages were sent with the machine, they were distinctly received in Kamina so long as the motor in Duala was running evenly; but so soon as it began to run unevenly, Kamina did not receive them. Transmission by means of the machine had the further disadvantage that in the meantime the battery could not be charged, whilst the noise of the machine made very difficult or even completely prevented the receiving of telegrams in the receiving room near by. In spite of all these difficulties, from August 1st to August 24th, 1914, 248 telegrams were transmitted for Kamina and these were all received and deciphered. The disturbances wilfully created by hostile wireless stations, by the Eiffel Tower for instance, did not seriously hamper the receiving of the telegrams. The wireless communication of the Eiffel Tower with French land stations could often be followed. During the very limited periods of leisure, attempts were made to disorganise hostile communications, for instance those between the Eiffel Tower and the wireless establishments on the English battleships, and those between the enemy's coast establishments.

The traffic to be coped with by the large Kamina wireless station was large, considering that generally telegrams in cipher were involved. During August 152 telegrams of 4,511 words were transmitted from Nauen to Kamina in 2,938 working minutes and in Nauen seventy-seven telegrams, of 1,828 words were received.

The hours most suitable for the receiving of telegrams were ascertained to be 1 a.m.—4.30 a.m. and 8 a.m.—1 p.m. The present writer was repeatedly one of the listeners and can testify to the clearness with which messages were received. Apart from a small local disturbance, caused by the breaking of a connection between the amplifier and the battery, no other disturbances occurred. The atmospheric influences were at times so strong

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during the hours just described as the most suitable for working, that operations were difficult.

At the large wireless station of Nauen, which on the outbreak of war was taken over by the Government and occupied by the military authorities, the antenna arrangement then consisted of one tower 250 m high, three frame towers of iron and one Rendahl mast, each 120 m in height. Between the towers was suspended an antenna, consisting of twenty wires, and directed towards Togo (Kamina); its natural wavelength was 4,000 m and its capacity 16,000 cm. As transmitting apparatus there were a quenched spark transmitter of 80 kW and a high frequency generator of about 100 kW. The frequency of the generator was 8,000 cycles, the spark transmitter worked with waves of 4,800, 6,500, 7,500, and 9,400, and the high frequency generator with waves of 9,400 and 4,700 m by means of frequency doublers.

THE DEFENCE OF THE LARGE WIRELESS STATION.

On the arrival of the field troops of the Togo Protectorate at the wireless station Kamina, it became urgently necessary to link together telegraphically important points of the defence zone, and to connect them with the probable main routes of the enemy's advance. A field telegraph division was formed for this purpose. Serious difficulties confronted the construction and operation of a sufficiently extensive and ramified field telegraph network. Trained men were lacking; the only ones available were the postal officials of the Protectorate. Moreover, apparatus and wire were strictly limited. Fortunately, when Lome was evacuated, all the stocks of telegraphic material which could be seized and transported, had been taken; this was supplemented by the post office stocks accessible from Kamina, especially those of the neighbouring Atakpame.

Essential to success was the training of suitable staffs for the construction and operation of the network. Europeans, whose profession or special qualities rendered them suitable for the task, were thoroughly trained as operators and as foremen for the laying of field lines, and coloured men were trained to do the more menial work; among the latter were the strong and industrious Kabure men, brought from the northern hinterland to Kamina by the Governor as labourers.

The most important strategical centre was located at Kamina, constituting the headquarters of the system. It was connected with the receiving house of the large wireless station by utilising a pair of conductors of a cable previously laid for lighting purposes. The rest of the lines were made of the excellent bronze wire, 3 mm diameter, belonging to the imperial telegraph service; this wire was attached to natural supports (trees, etc., or rude poles), but in many places it had to lie on the ground. As far as practicable, the existing network of the postal service of the railway was used along with the improvised system. The chief technical centre was set up at the railway station of Agbonu, the terminus of the hinterland railway from Lome, by utilising an exchange cabinet taken from the equipment of the postal service. Generally earth return was employed, metallic circuits only being used

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where cores were available. Intermediate stations were connected in parallel. Considerable stretches had in some cases to be linked up. A postal service with several deliveries daily was established between Kamina and Atakpame, where the European soldiers were quartered.

The strategical situation soon necessitated an extension of the network towards the south-west, from which direction the French might be expected to approach from Dahomey. The field telegraph station Njamassilä served as point of support for scouting operations in the direction of Dahomey, and communicated by means of a cyclist corps with the more advanced scout troops.

Two principles had to be kept steadily in view during the defence: (1) to hold and operate as long as possible the large wireless station, and (2) when it had to be surrendered, in no case to let it fall into the enemy's hands in working condition—such were the repeated injunctions of the Colonial Office.

Military considerations determined the line of conduct to be adopted in respect of the former of these two principles. The narrow Protectorate of Togo, enclosed between English and French possessions, disposed of very scanty forces (a police troop). For the defence there were available 150 Europeans (many of them not soldiers)—these, in so far as they were not used for other purposes, were formed into a European company, and the police troop of the Protectorate, about 400 coloured men, the majority of whom were reservists or recruits. It was impossible to man a line of defence round the entire station, including the portion of the aerial absolutely essential for the working of the station. That would have required 6,000 men. The Vice-Governor thought to make the power house, the workmen's house and the receiving house the last points of defence, and to proceed to the work of destruction when these buildings became untenable. Thus the destruction would be deferred as long as possible, but it was very doubtful if it could then be made complete. Besides, it would be impossible to continue the working of the station once the enemy had occupied the antenna region outside these buildings, because he would naturally at once have destroyed the antenna.

After consultation with the senior officers and the representatives of the Wireless Telegraph Company, it was decided that the destruction of the power house and the receiving house would not suffice to render the wireless station useless; the towers must not be allowed to remain standing. Otherwise, by means of transmitter appliances obtained from battleships or elsewhere, the enemy might either disturb or intercept the communications of other German wireless stations (Duala, German merchant vessels and warships, perhaps even the Nauen—Windhoek traffic) and might obtain valuable additions to his own means of sending news between Kamina and English and French wireless stations in West Africa on the one hand, and England and France on the other. From four to five hours were considered necessary to destroy the station and throw down the towers. When to begin the destruction must be determined by the military situation, *i.e.*, it had to be begun when the capture of the wireless station might be expected within four or five hours.

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The Imperial Colonial Office was asked for instructions. Its answer of August 16th ran " Measures left to discretion of men on the spot. Important station must in no case fall intact into enemy hands."

After this, the defence methods hitherto adopted had to be changed. Trench digging was discontinued. The existing network of field telegraph stations protected by sentries or larger forces was extended, so that the Governor, by means of continuous communications received from them at Kamina, was kept exactly informed of every change in the situation in the whole of the defence zone.

This change necessitated still greater exertions on the part of the field telegraph division; fresh stations had to be added to the network, *e.g.*, south of Kamina, on the Chra and in Amuno. For lack of time, bare copper wire had frequently to be laid on the ground for long stretches. As was to be expected, the extension of the line eastwards, towards Tscheti, was extraordinarily difficult. The difficulties began on the way to Awagome, a resting place on the road from Atakpame to Sakode. The Kabure men used as wire carriers, weary of their burden, had thrown away most of the coils of wire and fled into the bush. With great pains a sufficient quantity of wire was sent to Awagome, the starting point of the new line, to begin the work of construction. This work was attended with all the difficulties such bush terrain can present. Apart from two white and one coloured post messenger, told off to run the station, only Kabure men were available, and these, besides being totally ignorant, had lost their morale through the uncertainties of the campaign and displayed but little of the willingness and zeal with which they are usually credited. The terrain was as unfavourable for the construction of the line as it possibly could be. Where grass, high as a mounted rider, did not impede the advance, fallen trees did, or stout tree roots running across the path, or large stones and pools of water, or unbridged streams swollen by rains; it was often impossible to proceed before the obstacles had been removed or bridged. Such hardships added to the lack of food and an incessant tropical downpour made the men so disinclined to work that only extreme rigour could induce them to hold out. If the construction were not completed before nightfall, it would be impossible to count on a sufficient number of men for the next day.

When night fell, the intended terminus had not been reached by several kilometres. A trial of the line was made at a temporary station in the forest, and with great delight it was found possible to speak with Kamina, in spite of the loss of current along the bare wire laid in wet grass, although " ringing up " was not practicable. It was arranged that this new station should be switched on to the line and announce itself ready to receive news at fixed intervals. The next day the line was lengthened as far as the village Agbakovhe. From Agbakovhe cyclists communicated with the post stationed on the river Monu, whence scouts reconnoitred further in the direction of the enemy. The new station rendered especially valuable service, as the French were advancing from this quarter.

The field telegraph system worked satisfactorily throughout the campaign. Few interruptions occurred and these were quickly remedied. This was

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due to the excellence of the material employed and the zeal of the employees, whose devotion in their hard task was most praiseworthy, in spite of insufficient food supplies due to bad roads and the lack of reliable carriers.

Special care had to be exercised in the working of the system in order to prevent coloured men from communicating damaging news to the enemy. It was arranged to speak only German on the field lines, to man continuously the various stations with at least one European and to carry on no private conversations.

The method of defence adopted proved itself excellent. A systematic scouting service was arranged and the results speedily announced to the commander, thus enabling him to dispose of his forces to best advantage and send his orders immediately to the remotest points. The capitulation of the large wireless station was in the end inevitable in view of our inferiority in men and munitions, but it was delayed until August 27th, 1914, after a battle had been fought on the Chra (47 km south) inflicting heavy losses on the enemy and retarding his advance.

THE DESTRUCTION OF THE STATION.

After the commander had given orders to destroy the large wireless station, the work of destruction was carried out as follows: On a signal being given by steam sirens, the members of the thoroughly drilled "blasting division" (employees of the Wireless Telegraph Company and other Europeans and natives) took up their positions and the "evacuation police" completely evacuated the endangered terrain; then the director of the operations, standing near the engineers' house from which he had an unimpeded view in all directions, gave the order by telephone to the receiving house (northern stay mast of the aerial) and by cyclists to the post by the southern stay mast of the aerial: (1) to let down the receiving antenna. As soon as the antenna had fallen it was to be cut by men detailed for that purpose. Simultaneously by telephone order was given (2) to destroy the receiving room and (3) to destroy the power house. Apparatus, machines, auxiliary appliances were for the most part blown up or broken in pieces, written documents, drawings etc., were burnt. Then the order was given (4) to destroy the transmitting antenna. The antenna was loosened at several points and, after it had fallen, cut through in different places. The men then proceeded (5) to pull down the towers by loosening the back-stays attached to the stay-wire foundations. The towers fell with a loud crash full length in the desired direction, some of them being telescoped. The frame was completely bent. It was told how the crash of the falling towers could be heard far away in the silent night.

Although the station had to be destroyed during the night and under a cloudy sky, the work was carried out without untoward incidents. Fortunately there were no discharges of atmospheric electricity, which might have defied all the care taken to prevent harm to the men involved. An enemy surprise had to be reckoned with—English officers told the present writer that scouting parties had been in the immediate neighbourhood shortly before the towers were pulled down—and consequently the destruction had to be accelerated as much as possible. It was accomplished in

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four and a half hours, two and a half hours longer than had been anticipated owing to the difficulties caused by darkness and the rusting of the back-stay screws. It has been stated by our enemies (No. 81 of the *Wireless World*, of 1919) that we ought to have contented ourselves with putting the large wireless station out of action, but that we ought not to have destroyed unessential parts. In reply it must be emphasised that the destruction was an inevitable consequence of the war. Such an important instrument of communication could not be allowed to fall into the hands of the enemy who could have used it for his own purposes and inflicted great harm with it on his antagonist. In particular, our enemies would have been able to disturb the communication between German warships and especially that between the wireless stations Duala and Windhoek and between Windhoek and Nauen. If, on the other hand, only important parts had been destroyed, those parts which had remained intact might have been made workable again by means of supplementary parts or have been utilised for warlike purposes elsewhere. In any case they would have increased the armaments of the enemy. As, moreover, it was the duty of the defender, to keep the station in working order as long as possible, the destruction of the establishment which with its nine lofty towers occupied an extensive terrain had to proceed with the utmost dispatch, otherwise it would have been incomplete on the arrival of the enemy whom the meagre defensive troops might indeed delay, but could not repulse. For this reason, the destroyers were unable leisurely to select those parts which they deemed sufficient to prevent the station being put again in working order in a short time. A further principle guiding the work of destruction was that valuable technical secrets should not get into enemy hands, especially seeing that neither English nor French had hitherto succeeded in establishing reliable wireless communication over such distances in the tropics.

Had the large wireless station destined to join Germany with her African colonies been erected in the interior of Kamerun, it is highly probable that it could have held out longer than the Kamina station, so unfavourably situated in case of war. Presumably the Kamerun campaign would from the outset have been carried on more energetically and troops would have been taken for it from the Togo enterprise, nevertheless it seems certain that the capture of the station would have been considerably later. Disregarding, therefore, the above-mentioned important reasons for selecting Togo and bearing in mind only the course of the military operations, one is compelled to admit that Kamerun would have been preferable as a situation for the wireless establishment.

Thus did the first large wireless station to be erected in the tropics fall a sacrifice to Bellona. Though not yet definitely taken over, Kamina satisfied the enormous demands made upon it by the circumstances of the war. It was fortunate that this important station had been completed just before the outbreak of hostilities and that, after the destruction of cable connections, communication with the motherland was still possible. Although an inauspicious fate cut short the time of its active life, Kamina will ever remain an important landmark in the development of world traffic.

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Notes.

Personal.

Frederick A. Kolster, who is well known as the inventor of a direct reading decremeter, and for other useful contributions to the radio art, has resigned from the Bureau of Standards, Washington, D.C., to take up an appointment with the Federal Telegraph Company, California. [2520]

M. Blondin, the director of the *Revue Générale de l'Électricité*, has been nominated a Chevalier of the Legion of Honour. [2467]

Mr. Frederick G. Simpson, electrical engineer, formerly chief engineer and general manager of Kilbourne and Clark Manufacturing Company, and the Ship Owners' Radio Service, Inc., has established offices at the L. C. Smith Building, Seattle, Washington, for the design and construction of electric plants of all descriptions. [2541]

Dr. Leonard F. Fuller, the designer of the American type high and low power Poulsen arc transmitters, has entered the service of the Wireless Improvement Company, who have their works and offices in Jersey City, New Jersey, U.S.A.

Dr. Fuller will have charge of the design, construction, development and research work in connection with all arc transmitters to be manufactured by this company in the future.

Prior to joining the Wireless Improvement Company, Dr. Fuller's work included the design of such arcs as the 1,000-kW units installed in the Bordeaux (France) station, which are the largest in the world, as well as of practically all of the high and low power stations of the American Navy Department. [2569]

Commercial.

PERUVIAN POSTS AND TELEGRAPHS.— By agreement with the Peruvian Government, Marconi's Wireless Telegraph Co., Ltd., will on May 1st take over and operate for a period of twenty-five years the whole of the postal, telegraphic and wireless services of Peru, receiving as remuneration 5 per cent. of the gross receipts of the services and 50 per cent. of the annual profits. Sir William Slingo, late Engineer-in-Chief of the British Post Office, has accepted the position of Chief of the Peruvian Postal and Telegraphic Department. Of the approximately 9,000 miles of telegraphic communication in Peru some exist at a height of 16,000 feet, notably where crossings of the Andes are made.

The concession includes the sole and exclusive operation of all international wireless telegraph stations within the Peruvian Republic, and the exclusive right to erect any further wireless stations that may be considered necessary. [2210]

Information from Washington indicates that the difficulties which had arisen in connection with the high-power wireless stations which the American Federal Company was to erect at Shanghai have yielded to diplomatic pressure. The work of erection is expected to occupy about eighteen months. Stations are to be erected at a later date at Canton, Pekin and Kharbin. The putting into operation of the Shanghai station should, it is believed, enable direct wireless communication across the Pacific without the intervention of relay stations. [2274]

VENEZUELA RADIO PLANS.—A definite programme has been established by the Venezuelan Government for the installation of twenty-two wireless stations including in particular stations at the following places: Maracay, San Cristobal, Maracaibo, Puerto Cabello, Coro, La Guaira and Ciudad Bolivar. [2279]

A HIGH-POWER STATION FOR WARSAW.— It is announced by the Radio Corporation of America that the new high-power station to be built by them at Warsaw (see Note No. **2368** on p. 205 of our last issue) is to be equipped with Alexanderson alternators. [2464]

The radio station at Cape Cod, owned by the Radio Corporation of America, has recently been opened for general public service on wavelengths of 600 and 2,200 metres, using C.W. or interrupted C.W. transmission. Call letters WCC. Coastal station charges ten cents per word, no minimum. The receiving station is located at Chatham, Mass.

A spark station has also been opened for general public service at New Brunswick, for traffic on 300, 450, and 600 metres wavelength. Call letters WYN. Coastal station charges ten cents per word, no minimum. The receiving apparatus is located at Belmar, N.J.

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On and after May 1st, the station rate will be increased to eight cents per word (with no minimum) for all vessels controlled by the Radio Corporation of America. Vessels operated under contract with the U.S. Shipping Board will continue to apply the existing four cents rate. [2542]

General.

SISCONSET RADIO STATION.—A new radio station has been opened by the International Radiotelegraph Company at Sisconset, on Nantucket Island, Mass. Current for operating the plant is obtained from a storage battery which is charged when necessary by means of a gasoline-driven generator set. The transmitter is of the spark type and of 2 kW capacity. [1505]

An American radio record was scored by the U.S. Navy when the Goat Island radio station reported that messages had been sent within three minutes from Cavite, Philippine Islands, to Washington, D.C., a distance of 10,000 miles. [2288]

The radio station on the island Phu-Quoc (Cochin China) was opened for public service in November last. The tariff for messages to any telegraphic office in Indo-China is 0.05 piastre per word. [2118]

TERMINAL MARKINGS FOR ELECTRICAL APPARATUS.—A Sectional Committee has been appointed by the Engineering Standards Committee to prepare a systematic plan for the marking of the terminals of electrical apparatus. This work follows on the meeting of the Electrotechnical Commission held in Brussels in March, 1920. [2219]

It will be recalled that in the Report issued last June by the Imperial Wireless Committee it was recommended that a system of Imperial wireless communication should be established through a chain of stations 2,000 miles apart. It was suggested that the technical details of the scheme should be worked out by a special commission. The members of this body which included Lord Milner, Dr. Eccles, Mr. L. B. Turner and Mr. Shaughnessy are, with the exception of Lord Milner, now engaged in a detailed investigation of the scientific and engineering problems involved and are expected to make a report during the next two months. [2275]

HIGH-SPEED WIRELESS TELEGRAPHY BETWEEN ALDERSHOT AND COLOGNE.—A short account of special high-speed tests conducted on February 9th, 10th and 11th, at 100 words per minute. The results showed that 83 per cent. of the messages were received with perfect slip; of the remaining 17 per cent., 9 per cent. had errors which were readily corrected at sight and due primarily to maladjustment of the apparatus; and the remaining 8 per cent. contained errors which necessitated repetition. Short trials were also undertaken at 150 words per minute with good results. The transmitter consisted of a 1½-kW valve set, while at the receiver a three-valve H.F. amplifier, Turner valve relay, valve amplifier and double valve relay were employed all in cascade.—*Post Office Electrical Engineers' Journal.* [2519]

The radiotelegraphic branch of the Department of Naval Service, Canada, announces the opening of a new radiotelegraphic direction finding station near Red Head on the east side of the entrance to the harbour, and 1·93 miles from Partridge Island Lighthouse. The new station has been named St. John, N.B., Direction Finding Station and has call letters of VAR. The wavelength to be used for transmission and reception is 800 metres. [1683]

An announcement was made on March 23rd last by the President of the Radio Corporation of America to the effect that the United Fruit Company had acquired a substantial minority interest in the Radio Corporation of America and that they will be represented on the Board by Mr. George S. Davis, who has been elected a director of the Corporation. [2568]

The A.S. Norsk Marconi Kompani has declared a dividend at the rate of 5 per cent. for 1920, making with the interim distribution a total of 15 per cent. for the year. [2581]

In a "Notice to Airmen" recently issued by the Air Ministry instructions are given as to the employment by aircraft of the wireless direction finding stations established by the British Navy at nine points along the British coasts. [2055]

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Review of Radio Literature.

1. Abstracts of Articles and Patents.

(A.) Radio Stations and Installations (General and Descriptive Articles).

1755. The Organisation of a Subterranean Wireless Station at Paris during the War (Trocadero Station). (*Radioélectricité*, 1, pp. 14—18, June, 1920.)
An illustrated description of the installation at the Palais du Trocadéro, Paris.

1756. **H. Sauvé.** The Radio Station at Bamako (Soudan). (*Radioélectricité*, 1, pp. 348—351, December, 1920.)
A brief description with exterior views.

1757. Remote-control Panel for Radio Stations. (*Scientific American*, 124, p. 123, February 12th, 1921. *Technical Review*, 9, p. 16, April 5th, 1921—Abstract.)
A short note *re* a new arrangement of distant control panel, but giving no technical details.

1758. Extensions to the Nauen Radio Station. (*L'Électricien*, 52, p. 133, March 15th, 1921.)
A short note giving some details of the latest installation.

1759. **W. Ison.** Rome (San Paolo) Station. (*Everyday Science*, 2, pp. 503—504, January, 1921.)
A short illustrated description.

1760. **E. W. Welch.** The Great Pre-War World Wireless Scheme in Germany. (*Telegraph and Telephone Age*, 39, pp. 102—104, March 1st, 1921. *St. Martin's le Grand*, 31, pp. 24—28, January, 1921.)
An abstract of an article published in the *Archiv für Post und Telegraphie*. See RADIO REVIEW Abstract No. 1426, February, 1921; also pp. 68—75, February, 1921; and pp. 250—261 in this issue for translation.

1761. Radio from Shanghai to Washington. (*Telegraph and Telephone Age*, 39, p. 104, March 1st, 1921.)
Reference to the high-power radio stations to be erected by the Federal Telegraph Company in China for direct communication with San Francisco and Washington. See RADIO REVIEW Note No. **1996**, p. 154, March, 1921, and No. **2274**, p. 262, in this issue.

1762. The Nauen Radio Station. (*Science and Invention*, 8, p. 880, December, 1920.)
A general illustrated description.

1763. **A. C. Forbes.** A 300 kVA Transmitter at Bolinas, California. (*Science and Invention*, 8, pp. 757 and 780, November, 1920.)
A brief illustrated description of the installation.

1764. Eilvese Radio Station. (*Science and Invention*, 8, p. 881, December, 1920.)
A short illustrated description.

1765. **S. R. Winters.** Radio Stations to Improve Air Mail Service. (*Wireless Age*, 8, pp. 12—13, January, 1921.)
A short illustrated note with regard to fifteen radio stations for use in connection with the U.S. Post Office Air Mail Service.

1766. **J. O. Smith.** Thousand-Mile Amateur Radiophone. (*Wireless Age*, 8, pp. 11—15, March, 1921.)
A detailed illustrated description of an installation at Valley Stream, L.I., U.S.A., which has communicated by radiotelephony over ranges up to 1,300 miles using an antenna current of approximately 3 amperes.

1767. Wireless Telegraphy in the Belgian Congo. (*L'Électricité pour Tous*, 2, pp. 207—213, September, 1920.)
A general illustrated account of radio developments in the Belgian Congo extracted from a book with the same title by **R. B. Goldschmidt** and **R. Braillard.**

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1768. Transocean Radiotelegraphy. (*L'Électricité pour Tous*, 3, pp. 11—13, January, 1921; pp. 43—45, February, 1921.)
An illustrated article describing briefly the Alexanderson machines, and the Towyn wireless receiving station.

1769. **de Bouillane.** Wireless and the Mercantile Marine. (*Radioélectricité*, 1, pp. 280—284, November; pp. 325—335, December, 1920; pp. 443—447, February, 1921.)
General illustrated descriptions are given of Marconi and C.G.R. ship installations; and also those of the Japanese Annaka Company, the Société des Télégraphes Multiplex (system Magunna).

1770. Japanese Transmitting Station, Haranomachi. (*World Wide Wireless*, 2, p. 3, January, 1921. *Elektrotechnische Zeitschrift*, 42, p. 161, February, 1921—Abstract.)
A short note illustrating the reinforced concrete mast, 664 feet high.

1771. Quenched Spark Wireless for Ships. (*Times Engineering Supplement*, 17, No. 557, p. 106, March, 1921.)
A short note with regard to a new pattern of 1½-kW quenched-spark ship type transmitter manufactured by the Marconi Company.

1772. **J. A. Payne.** Radiophone Transmitter on the U.S.S. *George Washington*. (*General Electric Review*, 23, pp. 804—806, October, 1920.)
A short description of the installation fitted by the General Electric Company, U.S.A., on the U.S.S. *George Washington* for the use of President Wilson when crossing from France to America after the Peace Conference. See also RADIO REVIEW Abstract No. 1773.

1773. **H. H. Beverage.** Duplex Radiophone Receiver on U.S.S. *George Washington*. (*General Electric Review*, 23, pp. 807—812, October, 1920.)
An illustrated description of the receiving apparatus used on the U.S.S. *George Washington* in connection with the transmitting apparatus described in previous abstract. The arrangement of double aerials is described together with the circuit diagram of the apparatus and amplifiers.

1774. Modern Marine Wireless Apparatus. (*Electrician*, 86, p. 381, April 1st, 1921.)
A short illustrated description of quenched-spark wireless apparatus manufactured by Messrs. Siemens Brothers & Co. for marine use.

1775. **E. M. Kinney.** Radio Apparatus for Aircraft and Ground Stations. (*Proceedings of the Engineers' Society of Western Pennsylvania*, February, 1920.)

1776. Wireless Telephone for Aeroplane Stations on the London to Paris Line. (*The Times*, No. 42,428, p. 13, June 4th, 1920. *Elektrotechnische Zeitschrift*, 41, p. 759, September 23rd, 1920—Abstract.)

1777. Wireless Railroad Signals. (*Wireless Age*, 8, pp. 10—11, January, 1921. *Electrical World*, 77, p. 554, March 5th, 1921—Abstract.)
A short illustrated description of the method of signalling to railway trains in which a loop is suspended beneath the locomotive from which oscillating currents are sent by means of a three-electrode valve. A tuned circuit on the track causes indications to be given in the cab of the locomotive.

1778. **F. Limon and G. Lebaupin.** The Reception of Signals on Locomotives. (*L'Électricien*, 52, pp. 121—126, March 15th, 1921.)
The Augereau system * is described and illustrated.

1779. **L. de Forest.** Setting Up an Amateur Station. (*Experimental Science*, 1, pp. 21—23, May, 1920.)

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* See also RADIO REVIEW Abstract No. 566, July, 1920.

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1780. **S. C. Hooper.** Sketch of Present Radio Situation Influence on Tactics and Strategy. (*Proceedings of the U.S. Naval Institute*, 46, pp. 1209—1218, August, 1920. *Elektrotechnische Zeitschrift*, 42, p. 87, January 27th, 1921—Abstract. *Radio-électricité*, 1, pp. 507—508, March, 1921—Abstract.)

A paper presented to the U.S. Naval Institute reviewing the whole wireless system of the U.S. Navy, including radio compass apparatus.

1781. **L. H. Maertens.** Radiotelephony in the East Indies. (*Radio Nieuws*, 4, pp. 12—16, January, 1921.)

A brief account of tests made with two ½-kW Marconi sets.

1782. **J. H. C. Harrold.** Wireless Telegraphy: Its Application and Value to the Marine Service. (*Nautical Magazine*, 105, pp. 309—311, April, 1921.)

Some statistics are given with regard to the value of wireless to the merchant service and the fitting of all lighthouses and buoys with automatic wireless transmitting apparatus is described. Some special installations send out specified combinations of signals with which ships can take bearings with their D.F. apparatus.

1783. Wireless Transmission applied to Telegraphy and Telephony by Wire. (*Technical Review*, 8, p. 190, February 22nd, 1921. Abstracted from *Export and Import Review*, Berlin, October, 1920.)

Deals with the application of triode valves to multiplex telegraphy and telephony along wires.

1784. **A. Stein.** Marine Uses of Radio. (*General Electric Review*, 24, pp. 187—189, February, 1921.)

A short article describing in a general way the various applications of radiotelegraphy and telephony, and radio direction and position finding.

1785. The Development and Commercial Application of Radio Communication. (*General Electric Review*, 23, p. 793, October, 1920.)

Editorial comment on the development of C.W. transmitters.

1786. **W. H. G. Bullard.** The Application of Radio to Navigation Problems. (*Journal of the Franklin Institute*, 190, pp. 903—904, December, 1920.)

A short abstract of a lecture delivered before the electrical section of the Franklin Institute, which summarised the chief marine uses of wireless.

1787. **T. C. Harrison.** Some Notes on Wireless Telegraphy. (*Practical Engineer*, 63, pp. 118—120, February 24th, 1921.)

A *résumé* of the historical developments of wireless telegraphy.

1788. **L. M. Dunham.** Wireless as a Hobby. (*Telegraph and Telephone Age*, 39, pp. 7—8, January 1st, 1921.)

1789. Origin and Development of Radio Service in America. (*Telegraph and Telephone Age*, 39, pp. 54—55, February 1st, 1921. *Wireless Age*, 8, pp. 13—14, February, 1921.)

A general article summarising the introduction of wireless working into America, and with Admiral **Bullard's** part in encouraging the formation of the **Radio Corporation of America.**

1790. **C. G. Crawley.** Wireless Communication. (*Telegraph and Telephone Journal*, 7, pp. 92—93, March, 1921.)

An address delivered before the Telephone and Telegraph Society of London summarising the various types of wireless communications—between ships, aircraft and fixed stations. Summaries are given under the headings Naval, Mercantile Marine, Mercantile Operators, Coast Stations, D.F. Stations, Aircraft Wireless Telephony, Imperial Chain, High-power Stations. A section is also included comparing wireless and cable communications.

1791. **J. H. Dellinger.** Long Distance Radio Telephony now Practical. (*Electrical World*, 77, pp. 142—143, January 15th, 1921. *Scientific American Monthly*, 3, pp. 157—162, February, 1921—Abstract.)

A short article summarising recent progress in radiotelephonic transmission and dealing also with the most important problems at present requiring solution—such as the elimination of disturbances and interference, the provision of a reliable calling signal and the development of the maximum possible number of multiplex routes with wire-directed radio transmission.

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1792. **L. B. Atkinson.** Electrical Science and Industry. (*Journal of the Institution of Electrical Engineers*, 59, pp. 1—20, December, 1920. *Electrician*, 85, pp. 616—619, November 26th, 1920—Abstract.)

The Inaugural Presidential Address to the Institution of Electrical Engineers. In the course of the Address recent progress in wireless signalling methods is summarised.

1793. Radiotelegraphy and Telephony in 1920 and 1921. (*Electrician*, 86, pp. 94—95, January 21st, 1921.)

A general summary arranged under the following headings: The Development of the Thermionic Valve, the Development of High-powered Stations, Progress in Reception, Wireless Telephony, Progress in Arc and C.W. Stations, Commercial Items, Lines for Future Developments, the Secrecy Problem, Wireless Control Systems and the Chief Problems for the Future. In the last section the following items are included as requiring development or solution: An efficient trigger relay, a valve which operates without filament battery, high-power vacuum tubes, a more reliable form of high-frequency alternator, new limiters and X-eliminators, methods of eliminating spark interference during C.W. reception.

1794. International Radiotelegraphy. (*Electrician*, 86, p. 242, February 25th, 1921.)

An editorial note with regard to the activity in establishing high-power radio service in various countries.

1795. **A. N. Goldsmith.** Transocean Telephony. (*Telegraph and Telephone Age*, 39, p. 10, March 1st, 1921.)

A short abstract of a lecture and demonstration at the College of the City of New York, in which reference was made to recent long distance radiotelegraph and telephone communication.

1796. **C. G. Crawley.** Wireless Waves. (*St. Martin's le Grand*, 31, pp. 10—13, January, 1921. *Telegraph and Telephone Age*, 39, pp. 128—129, March 16th, 1921—Abstract.)

A popular article outlining the chief methods of wireless communication. See also RADIO REVIEW Abstract No. 1338, January, 1921.

1797. **J. O. Smith.** Amateur Spark and C.W. Transmission. (*Wireless Age*, 8, pp. 11—12, February, 1921.)

A critical comparison of the two methods of transmission.

1798. **E. F. W. Alexanderson.** Central Stations for Radio Communication. (*Telegraph and Telephone Age*, 39, pp. 2—5, January 1st, 1921. *Electrician*, 85, pp. 657—658, December 3rd, 1920. *Engineer*, 121, p. 331, March 25th, 1921.)

An abstract of a paper read before the Institute of Radio Engineers on November 10th, 1920. (See also Note No. **1823** on p. 99 of the February issue.)

(B.) Spark Gaps and Spark Transmitting Apparatus.

1799. **L. Bouthillon.** On the Charging of Condensers by an Alternating E.M.F., and their Discharge through a Spark Gap. An Investigation of the Conditions for the Production of a Musical Note. (*Radioélectricité*, 1, pp. 286—291, November, 1920; pp. 448—454, February, 1921; pp. 533—546, April, 1921.)

A very mathematical discussion not suited for an effective abstract. The original should be consulted.

1800. New Type of Radio Transmitter. (*Telegraph and Telephone Age*, 39, p. 67, February 1st, 1921.)

A new pattern of radiotelegraph transmitter is briefly described and illustrated. It is manufactured by the Wireless Speciality Apparatus Company, of Boston, U.S.A., and the special feature of interest is the provision of a magnetically controlled wave-changing switch, permitting the complete remote control of the transmitter, and the almost instantaneous change to any one of four wavelengths for which the set is adjusted.

1801. **J. D. Morgan.** Impulsive Sparking Voltages in Small Gaps. (*Philosophical Magazine*, 41, pp. 462—469, March, 1921.)

Some experimental curves of sparking voltages are included in the article.

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1802. **H. E. Hallborg.** Self-cooled Quenched Gap. (*Wireless Age*, 8, pp. 19—20, February, 1921.)
Constructional arrangements and parts of this gap are described and illustrated.

1803. **F. Perrin.** On Radio Stations with Synchronous Rotary Spark Gaps. (*Radioélectricité*, 1, pp. 503—506, March, 1921.)
A mathematical discussion of the charging and discharging of a condenser synchronously with the A.C. supply, as with a rotary spark gap having the same number of teeth as there are pairs of poles on the alternator. Curves are worked out giving the maximum sparking voltage and the efficiency in terms of the ratio $L\omega/R$, as well as the variation of voltage across the condenser terminals throughout the charging period.

1804. **M. Brossier.** Undamped Oscillation Generators. (*Radioélectricité*, 1, pp. 115—127, August; pp. 175—183, September; and pp. 225—240, October, 1920.)
General descriptions are given of timed spark, arc, H.F. alternator, and valve transmitting apparatus, with illustrations of installations at some high-power stations.

(C.) Arc Apparatus.

1805. **E. W. Stone.** The Poulsen Arc. (*Proceedings of the U.S. Naval Institute*, 46, pp. 1049—1073, July, 1920. *Technical Review*, 7, pp. 357—358, December 14th, 1920.)
Gives a *résumé* of the mode of operation of arc oscillation generators, with circuit diagrams of the arrangements and good illustrations of large arc installations.

1806. **Westinghouse Lamp Company.** Continuous Wave Transmitter. (*French Patent* 505633, October 31st, 1919. Published August 3rd, 1920.)
The specification describes an oscillation generator of the arc type which consists of two main electrodes and an auxiliary mercury electrode serving for starting the arc. See also *British Patent* 135185.*

1807. The Arc Generator as an Engineering Mechanism. (*Electrician*, 85, pp. 648—651, December 3rd, 1920. *Science Abstracts*, 23B, p. 101, Abstract No. 198, March 28th, 1921—Abstract.)
A short illustrated description of the arc oscillation generators manufactured by **C. F. Elwell, Ltd.** Ten-kilowatt and 25-kW sets are illustrated together with parts of the latest type of 250-kW apparatus.

1808. **L. F. Fuller.** Duplex Operation by Two Arcs. (*Wireless Age*, 8, p. 20, January, 1921.)
An arrangement of two arc generators is described, each connected to its own aerial system so that simultaneous operation on different wavelengths may be used, or the two sets of apparatus may be operated together on the same wavelength, an additional circuit being provided for maintaining the oscillations in the two aerial networks in phase with one another. Signalling is effected by keying in this coupling circuit so that the oscillations in the two aerials are alternately thrown into and out of phase with one another.

(D.) High-frequency Alternators.

1809. **E. Blake.** The Alexanderson High-frequency Alternator. (*Wireless World*, 8, pp. 702—705, January 8th, 1921. *Telegraph and Telephone Age*, 39, p. 79, February 16th, 1921—Abstract.)
An illustrated description, covering similar ground to the article referred to in Abstracts Nos. 1209, December 1920; 1333, January 1921.

1810. **M. Latour.** The Production of High-frequency Currents by Dynamo-electric Machinery. (*Annales des Postes, Télégraphes et Téléphones*, 10, pp. 32—59, March, 1921.)
This paper contains practically the same material as those referred to in RADIO REVIEW Abstract No. 781, September, 1920. See also RADIO REVIEW, p. 491, July, 1920.

* RADIO REVIEW Abstract No. 407, June, 1920.

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1811. **J. Béthenod.** On the Self-excitation of Alternators by means of a Capacity. (*Radio-électricité*, 1, pp. 187—188, September, 1920.)
A short mathematical treatment of the subject based on Blondel's theory.

(E.) Static Frequency Raisers.

1812. **J. Zenneck.** The Theory of the Magnetic Frequency Transformer. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, pp. 2—21, January, 1921.)
An abstract of a paper which was read in New York in 1915. It has appeared in full in *Proceedings of the Institute of Radio Engineers*, 8, pp. 468—492, 1920. (RADIO REVIEW Abstract No. 1436, February, 1921.)

(F.) Thermionic Valves (and Valve Apparatus).

(1) AND (2) GENERAL DESCRIPTIVE ARTICLES.

1813. **L. de Forest.** The Audion: Its Action and some Recent Applications. (*Journal of the Franklin Institute*, 190, pp. 1—38, July, 1920. *Bulletin de la Société Belge des Électriciens*, 34, pp. 243—245, October, 1920—Abstract. *Science Abstracts*, 23B, p. 496, Abstract No. 946, October 31st, 1920—Abstract. *Radio News*, 2, pp. 208—210, October, 1920; pp. 280—282 and 333—335, November, 1920; and pp. 358—359, 386 and 388, December, 1920.)
A general historical account of the development of the audion followed by a consideration of the theory of electronic emission from hot filaments and some of the uses of three-electrode valve apparatus. Various radio sets using audions are illustrated and also several patterns of three-electrode tube.

1814. **H. J. van der Bijl.** Electron Relays as Amplifiers and Oscillators. (*Popular Science Monthly*, 96, pp. 132, 134, 136 and 137, April, 1920; pp. 132, 134, May, 1920; pp. 142 and 144, June, 1920.)
A popular descriptive article.

1815. Notes on the Three-electrode Valve. (*Model Engineer*, 43, pp. 406—408, November 18th, 1920; pp. 473—474, December 9th, 1920.)
A general descriptive article dealing with the various uses of the triode valve.

1816. **M. Brossier.** The Vacuum Tube in Radiotelegraphy. (*Radioélectricité*, 1, pp. 19—32, June; pp. 82—91, July, 1920.)
A general account of the multitudinous applications of two- and three-electrode valves, with illustrations of a number of types of French amplifiers, etc. Different types of valves are illustrated, with characteristic curves.

1817. Electronic Vacuum Tubes. (*L'Électricité pour Tous*, 3, pp. 75—77, March, 1921; pp. 107—109, April, 1921.)
A short general article with illustrations of typical patterns of valves.

1818. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Valve Detector. (*French Patent* 506594, November 26th, 1919. Published August 25th, 1920.)
Valves for receiving wireless signals have their anode circuits energised by the same battery as is used for heating the filaments—the voltage being preferably about six volts. The anode is a metal which is electro-positive to the filament.
There is a corresponding British application, No. 147816, of July 9th, 1920, the patent on which has not yet been granted. (British Thomson-Houston Company, assignees of **W. C. White.** Convention date October 11th, 1917.)

1819. **P. H. Boucheron.** Two New Vacuum Tubes. (*Wireless Age*, 8, pp. 15—16, February, 1921. *Electrical World*, 77, p. 498, February 26th, 1921—Abstract.)
A description of two new three-electrode vacuum tubes manufactured by the Radio Corporation of America.* A number of circuit diagrams are also given of various arrangements of amplifier.

* See also RADIO REVIEW Note No. **2170**, pp. 152 and 154, March 1921.

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1820. **J. Scott-Taggart.** The Use of Vacuum Tubes for Wireless Transmission and Reception of Continuous Waves. (*Journal of the Institution of Electrical Engineers*, 58, pp. 893—897, September, 1920.)

The paper is divided into two parts dealing respectively with the use of vacuum tubes for generating oscillations and a discussion of some modern methods for receiving C.W. signals by using the heterodyne principle. A second paper is also devoted to the production of high voltages for transmission circuits and the use of D.C. dynamos, induction coils and rectified alternating current is discussed.

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(3) THEORY AND PHYSICS OF THERMIONIC VALVES.

1821. **S. L. Ting.** Experiments on Electron Emission from Hot Bodies. (*Proceedings of the Royal Society*, 98A, pp. 374—391, February 2nd, 1921. *Chemical News*, 120, p. 272, June 4th, 1920—Abstract. *Nature*, 105, p. 441, June 3rd, 1920—Abstract.)

Experiments are described designed to be a continuation of experiments on the electron currents from metal discs and filaments made by Professor Richardson in 1907. In 1914 Schottky found a distribution of energy of the electrons from tungsten and carbon filaments to be in close accordance with Maxwell's law and the present experiments show that deviations from Maxwell's law if not general are at any rate quite common. With lime-coated platinum the emission energy is either exceptionally low or else the method of investigation gives illusory results. Data are also given showing interesting hysteretic effects in the electron currents. Possibly such effects indicate the presence of residual gas and the deviations from Maxwell's law may be in some way connected with such contamination.

1822. **H. W. King.** Calculation of the Constants of the Three-electrode Thermionic Vacuum Tube. (*Physical Review*, 15, pp. 256—268, April, 1920. *Science Abstracts*, 23A, p. 432, Abstract No. 1091, August 31st, 1920—Abstract.)

This paper has already been abstracted—RADIO REVIEW Abstract No. 423, June, 1920.

1823. **I. Langmuir.** Fundamental Phenomena in Electron Tubes having Tungsten Cathodes. (*General Electric Review*, 23, pp. 503—513, June, 1920; pp. 589—596, July, 1920. *Electrical World*, 76, p. 249, July 31st, 1920, and p. 537, September 11th, 1920—Abstract. *Technical Review*, 7, p. 221, November 16th, 1920—Abstract. *Science Abstracts*, 23A, p. 585, Abstract No. 1471, November 30th, 1920—Abstract. *L'Elettrotecnica*, 8, pp. 15—16, January, 1921—Abstract.)

The author discusses the fundamental factors including the operation of two and three-electrode electron tubes—such as the electron emission from the filament, the effect of space charge, the disturbances caused by the current passing through the filament, the effects due to the electrostatic charge upon the walls of the bulb, the effects caused by lack of uniformity in the temperature of the filament and the effects of external magnetic fields. The second part of the article discusses primarily the emission of secondary electrons from the walls of the bulb and from the electrodes. Typical characteristics are given for different conditions of operation and finally the effect of the grid in a three-electrode valve is considered mathematically.

1824. **A. Blondel.** Graphical Theory of Audion Generators and the Calculation of the Amplitude of the Oscillations. (*Radioélectricité*, 1, pp. 7—13, June, 1920; pp. 63—72, July, 1920; also p. 340, December, 1920.)

Covers similar ground to the articles referred to in Abstracts Nos. 352, May; 418, 419 and 422, June, 1920.

1825. **H. Vogel** and **M. Wien.** Acoustic Tongue Pipes and Triode Oscillations. (*Annalen der Physik*, 62, pp. 649—665, August 4th, 1920. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, pp. 56—57, January, 1921.)

An experimental study and discussion of the analogous phenomena occurring in tongue pipes and in triode oscillators with coupled oscillatory circuits. The phenomena known as "Ziehen," *i.e.*, the occurrence of the sudden phase change at different values of the tuning condenser according as its capacity is being increased or decreased, is shown to have its exact analogy in the acoustic experiment.

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1826. **F. H. Newman.** Absorption of Gases in the Electric Discharge Tube. (*Proceedings of the Physical Society of London*, 33, pp. 73—82, February 15th, 1921.)
A continuation of previous work. (See RADIO REVIEW Abstract No. 656, August, 1920.) It is concluded that the absorption is principally chemical in nature, and that it takes place very rapidly at clean freshly deposited metal surfaces.

(R.) Radio Direction Finding.

1827. **R. Mesny.** The Diffraction of the Electromagnetic Field by a Cylinder. (*Science Abstracts*, 23B, p. 495, Abstract No. 940, October 31st, 1920.)
See RADIO REVIEW, 1, pp. 532—540, August, 1920; and pp. 591—597, September, 1920.

1828. Telephoning over High-tension Lines. (*Scientific American*, 125, p. 544, November 27th, 1920.)
A brief reference to an installation of wired wireless telephony over a 11,000-volt line between Ocean City and Atlantic City, N.J.

1829. **W. Burstyn.** Wireless Telegraphy in Space. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 322—337, November, 1920.)
The problem of transmission between an aeroplane and a ground station is considered. The trailing aerial of the former is taken as being equivalent to a Hertzian oscillator inclined at about 20 degrees to the horizontal. Because of this position it shows a very strong directional action which leads to a complicated spacial characteristic. The received current is also dependent on the aerial arrangement of the ground station. The relation between the received current and the spacial relations of the aerials is written

$$S = k \cdot \frac{1}{b} \cdot \sin \xi \cdot \sin \eta$$

where S is the received current, k is a constant, b the distance between the stations, ξ the angle between the axis of the sending oscillator and the direction of radiation, and η the angle between the electric vector and the direction of the receiving Hertzian oscillator. Various special cases of this characteristic formula are discussed in detail (*e.g.*, the case in which the aeroplane while sending maintains a constant direction at constant height, or the case in which the aeroplane turns at an approximately constant distance, etc.). The possibility of errors in taking directional bearings on an aeroplane transmitter of this type is considered briefly, a further discussion being postponed for a later paper.

1830. **J. Hollingworth** and **B. Hoyle.** Local Errors in Radio Direction Finding. (*Technical Review*, 7, pp. 427—428, December 28th, 1920—Abstract.)
See RADIO REVIEW, 1, pp. 644—649, October, 1920.

1831. **G. Ferrie, R. Jouaust, R. Mesny** and **A. Perot.** Radiogoniometric Investigations. (*Comptes Rendus*, 172, pp. 44—57, January 3rd, 1921.)
The results of observations carried out by a special D.F. observing station erected at Meudon are set out briefly. The observations were made on signals from Lyons, Hanover, Rome, Nantes, Annapolis, Clifden and Moscow, and a chart is included summarising some large variations in apparent direction from the Hanover station. These variations were accompanied by bad minima of signal strength and their magnitude varied with the season of the year.

1832. **J. H. Dellinger.** The Radio Compass. (*Radio Amateur News*, 1, pp. 400—402, February, 1920.)
A general descriptive article.

1833. The European Direction-finding Stations. (*Radioélectricité*, 1, pp. 38—39, June, 1920.)
Includes tabular particulars of the principal British, French and German D.F. stations with a chart showing their positions.

1834. Marine Direction Finding. (*Radioélectricité*, 1, pp. 33—35, June, 1920.)

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1835. The Determination of a Ship's Position by means of Wireless Telegraphy combined with Submarine Sound Signals. (*Radioélectricité*, 1, p. 256, October, 1920.)

1836. **L. Fave.** Marine and Aerial Navigation. (*Comptes Rendus*, 172, pp. 252—254, January 31st, 1921.)
Includes some references to the uses of W/T.

1837. **J. Erskine-Murray** and **J. Robinson.** Wireless Direction-finding Apparatus. (*French Patent* 505571, October 29th, 1919. Published August 2nd, 1920.)
In order to enable vessels and aircraft to determine the direction of a transmitting station, it is proposed to provide the station with means for sending out signals in pairs at a definite angle apart, and means to provide that the signals are sent out in pairs in different directions.
See also *British Patent* 135896, RADIO REVIEW Abstract No. 505, July, 1920.

(S.) Distant Control by Wireless.

1838. **E. T. Jones.** Torpedo Controlled by Aeroplane. (*Wireless Age*, 8, pp. 30—31, October, 1920.)
Circuit diagrams of an arrangement due to **E. C. Hanson** are given. The torpedo carries an antenna suspended by a balloon.

1839. Radio Control of Naval Units. (*Scientific American*, 123, p. 442, October 30th, 1920.)

1840. Radio Control for Aeroplanes. (*Scientific American*, 123, p. 402, October 16th, 1920.)
A short note referring to the use of radio means for controlling pilotless aircraft.

(T.) High Frequency Wire Telegraphy and Telephony.

1841. **F. E. Pernot.** The Use of Alternating Currents for Submarine Cable Transmission. (*Journal of the Franklin Institute*, 190, pp. 323—371, September, 1920. *Electrical World*, 76, p. 792, October 16th, 1920—Abstract.)
Experiments with wired wireless communication for the Alaskan submarine cable system are described. Extended tables of measurements and other data are included together with curves of capacity attenuation constants and other similar factors.

1842. **J. Corver.** High Frequency Wire Telephony. (*Radio Nieuws*, 3, pp. 267—270, September, 1920.)

1843. **H. Fassbender,** and **E. Habann,** Circuit for High Frequency Line Telegraphy. (*German Patent* 312590, September 25th, 1918.)
A "wired wireless" circuit in which the transmitter also serves to generate the local oscillations required for beat reception (see Fig. 1).

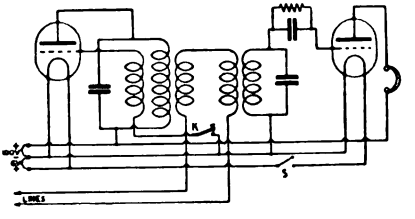

FIG. 1.

1844. **J. W. Kean.** Wired Wireless Experiments in the United States. (*Radio News*, 2, p. 134, September, 1920.)
A *résumé* of **G. O. Squier's** experiments. (See RADIO REVIEW Abstract No. 854, September, 1920.)

1845. **A. Gradenwitz.** Wired Wireless Experiments in Germany. (*Radio News*, 2, pp. 135 and 164, September, 1920.)
A *résumé* of Fassbender and Habann's experiments. See RADIO REVIEW Abstracts Nos. 1146 and 1179, November, 1920.

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(U.) Miscellaneous Methods of Communication.

1846. **T. W. Case.** Thalofide Photoelectric Cell. (*Electrical World*, 76, p. 1033, November 20th, 1920.) Also The Thalofide Cell, a New Photoelectric Substance. (*Physical Review*, 15, pp. 289—292, April, 1920. *Science Abstracts*, 23A, p. 587, Abstract No. 1477, November 30th, 1920—Abstract.)

A short note describing experiments on the use of new thalofide cells for photophonic transmission. An acetylene flame transmitter was employed.

1847. **H. Barkhausen** and **H. Lichte.** Quantitative Experiments on Sound under Water. (*Annalen der Physik*, 62, pp. 485—516, July 16th, 1920. *Science Abstracts*, 23A, pp. 577—578, Abstract No. 1456, November 30th, 1920—Abstract.)

1848. Leader Cables for Navigation. (*Times Engineering Supplement*, 17, No. 555, p. 32, January, 1921.)

An account is given of a demonstration of the apparatus installed at Portsmouth.

1849. **E. T. Jones.** Convoying Ships by Radio. (*Experimental Science*, 1, p. 7, May, 1920.)

Apparatus is described for guiding ships by a submerged cable.

(V.) Traffic Particulars of Radio Stations.

1850. The Development of Radio Traffic in Germany. (*Annales des Postes, Télégraphes et Téléphones*, 9, p. 593, December, 1920.)

A brief *résumé* of radio traffic from June, 1919, to June, 1920.

1851. The Reception and Transmission of Meteorological Bulletins for Ships. (*Radioélectricité*, 1, pp. 298—300, November, 1920.)

Tables are given of the principal stations circulating such reports.

1852. The Programmes of Press Transmission. (*La Nature*, 48(2), Supplement p. 183, December 4th, 1920.)

Particulars are given of the leading European high-power stations.

1853. German Wireless Press Service. (*Telegraphen- und Fernsprech-Technik*, 9, pp. 149—150, December, 1920.)

A description of experiments in the distribution of wireless news by telegraphy and telephony from Königswusterhausen which is fitted with a 1-kW valve transmitter (300 watts in antenna).

1854. **G. Bigourdan.** Corrections to the Normal Time Signals transmitted by the International Bureau de l'Heure between January 1st and March 19th, 1920. (*Comptes Rendus*, 171, pp. 600—605, October 4th, and pp. 643—645, October 11th, 1920.)

Tables are given of the corrections to the standard pendulum by which the transmission of the time signals is controlled, and also of the errors of the wireless telegraphic transmission.

1855. The Nantes Radio Station. (*Radioélectricité*, 1, p. 421, January, 1921.)

A short note stating that four new 180-metre towers are to be added to this station, enabling transmission to be effected with wavelength between 11,000 and 20,000 metres.

1856. Wireless Telephone to Geneva. (*The Times*, No. 42592, p. 7, December 13th, 1920.)

A report relative to wireless telephone transmission tests between London and Geneva *via* Chelmsford radio station. Speeches were sent to Geneva by Lord Burnham, Lord Riddell and Dr. Graham Bell speaking on an ordinary landline telephone instrument.

(W.) Radio Legislation (Agreements, Patents, etc.).

1857. International Communications Conference. (*Telegraph and Telephone Age*, 38, pp. 592—593, November 16th, 1920.)

Reference is made to the visits of the international delegates to the radio plants in the vicinity of New York.

1858. **P. Brenot.** International Radio Legislation. (*Radioélectricité*, 1, pp. 154—165, August; pp. 211—216, September, 1920.)

A summary of the main international laws fixed by the radio conventions, and now in force.

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1859. An International Postal, Telegraphic, and Radiotelegraphic Conference. (*Radioélectricité*, 1, pp. 108—111, July; pp. 168—169, August, 1920.)
A report of a conference held in Paris in July, 1920.

1860. Japanese Regulations concerning the Transmission of Public Correspondence by Private Telegraph Stations or by Private Radio Stations. (*Journal Télégraphique*, 44, pp. 127—130, August 25th, 1920. *Radioélectricité*, 1, p. 362, December, 1920; pp. 419—420, January, 1921.)

1861. Australian Wireless Restrictions. (*Electrical Review*, 87, p. 80, July 16th, 1920.)
Reference is made to the conditions under which wireless telegraph licences are granted.

1862. French Radio Legislation. (*Radioélectricité*, 1, pp. 52—55, June; pp. 102—104, July, 1920; also p. 165, August, 1920.)
A detailed statement of the French radio laws at present in force.

1863. British Radio Legislation. (*Radioélectricité*, 1, pp. 267—272, October, 1920.)
A summary is given of the laws at present in force.

1864. The Reception of Time Signals and Meteorological Telegrams in France. (*Radioélectricité*, 1, pp. 310—312, November, 1920.)
Details of legislation for this class of radio work.

1865. Wireless Telegraphy and Aerial Navigation. (*Radioélectricité*, 1, pp. 216—217, September, 1920.)
A summary of the French laws bearing on this phase of radio work.

1866. Wireless Telegraphy in Colombia. (*Electrical Review*, 87, p. 274, August 27th, 1920.)
Reference is made to a contract between the Colombian Government and Marconi's Wireless Telegraph Company for the erection of stations.

1867. Argentine Wireless. (*Elektrotechnische Zeitschrift*, 42, p. 42, January 13th, 1921. Abstracted from *Lateinamerika*, (A), pp. 230—231, 1920.)
Details of various interests which have obtained concessions for the erection of high-powered wireless stations in Argentine, but more especially of a German company founded jointly by Siemens and the A.E.G. under the name of the "Compania Radiotelegrafica Transradio" with the object of liberating South America from the English cable monopoly.

(X.) Biographical and Personal Notes.

1868. **D. C. Jackson.** Dr. Elihu Thomson—Scientist, Inventor and Educator. (*General Electric Review*, 23, pp. 983—984, December, 1920.)
A biographical sketch.

1869. **Thomas Thomassen Heftye.** (*Telefunken Zeitung*, 4, No. 21, pp. 3—4, July, 1920.)

1870. M. **Jules Carpentier.** (*Radioélectricité*, 1, pp. 5—6, June, 1920.)

1871. General **Messimy.** (*Radioélectricité*, 1, pp. 173—174, September, 1920.)
A short biographical notice with portrait.

1872. M. **Édouard Branly.** (*Radioélectricité*, 1, pp. 277—279, November, 1920.)
Some biographical notes, including a photographic reproduction of a wireless message received by M. **Branly** from Mr. **Marconi** on March 28th, 1899.

1873. M. **E. Brylinski.** (*Radioélectricité*, 1, pp. 323—324, December, 1920.)
Biographical notes.

1874. **L. Amaduzzi.** The Scientific Work of Professor **Righi.** (*Revue Scientifique*, 58, pp. 524—527, September 11th, 1920. *Scientia*, 28, pp. 467—472, December 1st, 1920.)

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1875. **A. Righi.** (*Radioélectricité*, 1, pp. 223—224, October, 1920. *Elektrotechnische Zeitschrift*, 41, p. 598, July 29th, 1920. *Comptes Rendus*, 171, p. 1251, December 20th 1920.)
Obituary notices.

1876. **M. R. de Valbreuze.** (*Radioélectricité*, 1, p. 240, October, 1920.)
A note with regard to the nomination of M. de Valbreuze as Chevalier of Legion of Honour.

(Y.) Historical Radio Articles.

1877. A Short History of Primitive Methods of Visual Signalling. (*Telegraph and Telephone Age*, 38, pp. 568—570, November 1st, 1920.)

1878. Seventy-five Years of Applied Electricity. (*Scientific American*, 123, pp. 331—333, October 2nd, 1920.)
Contains a brief review of telegraphic development from 1845 to the high power radio station of to-day.

1879. Electrical Engineering in 1920. (*Engineer*, 131, pp. 18—20, January 7th, 1921.)
A *résumé* of the most important wireless developments in 1920 is included.

1880. Telegraphy and Telephony (in Germany) Before, During and After the War. (*Archiv für Post und Telegraphie*, pp. 1—31, January, 1921.)
A review containing a section devoted to wireless.

(Z.) Miscellaneous Applications of Radio. Radio Nomenclature, etc.

1881. **F. H. Sykes.** Civil Aviation and Air Services. (*Aeronautical Journal*, 24, pp. 579—594, November, 1920. *Engineer*, 130, pp. 385—386, October 15th, 1920—Abstract. *Wireless World*, 8, p. 575, November 13th, 1920—Abstract. *The Electrical Review*, 87, pp. 603—604, November 5th, 1920.)
Includes some reference to the utility of wireless for aircraft services.

1882. Airplane and Flight Conditions. (*Everyday Engineering Magazine*, 10, p. 59, October, 1920.)

1883. Wireless Time Signals. (*Technical Review*, 87, p. 755, December 10th, 1920.)
Wireless telegraph equipment is being installed at the Huddersfield tramway offices, to pick up the Eiffel Tower (Paris) standard time signals. A governor clock has been fixed, and the tramway clock will be checked each day by the Paris message.

1884. **P. Schereschewsky.** Wireless and Meteorology. (*La Nature*, 49, (1), pp. 12—16, January 1st, 1921.)
A chart is given showing the position of the French meteorological stations and of the wireless communication routes used therewith; together with tables of the weather reports circulated by wireless containing the observations made at these stations. A chart is also given of the meteorological network for the whole of Europe.

1885. **J. Bethenod.** An Investigation of the Electrical and Radio Methods of Repeating Signal Indications on Locomotives. (*Radioélectricité*, 1, pp. 292—297, November; pp. 341—347, December, 1920.)

1886. Wireless Telephony as Police Aid. (*Electrical World*, 77, p. 60, January 21st, 1921.)
Refers to the use of wireless telephone apparatus in connection with police squads using automobiles.

1887. Christiania. (*Elektrotechnische Zeitschrift*, 42, p. 189, February 24th, 1921.)
A letter from **W. Dornig** of the Telefunken Company protesting against the adjective "gross" being applied to this station in a recent article, since its antenna power is only about 15 kW. He also states that it does not represent the best modern practice.

1888. The Bureau of Standards Radio Classification. (*Everyday Engineering Magazine*, 9, pp. 356—358, July, 1920.)
Full details are given of the proposed classification for information on radio subjects.

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1889. Standardising Radio Nomenclature. (*Everyday Engineering Magazine*, 10, pp. 66—67, October, 1920.)

Suggestions are made for a standardised lettering for the terminals and parts of radio apparatus. Some of the abbreviations given are also applicable to drawings and references in articles.

1890. **Ajax Metal Company.** Receiving Apparatus. (*French Patent* 496120, filed July 23rd, 1919. Dated October 28th, 1919.)

This specification describes a method of induction heating by the use of high frequency currents as obtained, for example, by a condenser discharge. The primary winding of the furnace is shown connected to supply conductors through a condenser in one conductor and inductances in both conductors. The conductors are shunted by a spark gap arranged between two pairs of inductances. An arrangement for polyphase working is also shown and it is stated that the arrangement is applicable to wireless telegraphy.

2. Books.

WIRELESS TELEGRAPHY AND TELEPHONY: An Outline for Electrical Engineers and Others. By L. B. Turner, M.A., M.I.E.E. (London: *The Cambridge University Press*. 1921. $8\frac{1}{2}'' \times 5\frac{1}{2}''$. Pp. xii + 195. Price 20s. net.)

In this book the author sets out to "provide for the large class of interested persons occupying an intermediate position" between "the wireless operator on the one hand and the specialist wireless engineer on the other." The subject is a large one and as usual some compromise has had to be made between the matter to be included and the space available. Different individuals rarely agree on a compromise of this kind but in the present instance it is difficult to find any serious fault with the author's choice. The book is one that can be read by any one who has reached the standard of a third year electrical engineering student and in some chapters one can almost hear the author holding forth to his undergraduates at Cambridge. The subject-matter is put forward in an accurate and interesting way, parts of the book reading like an enthralling novel! The very latest and most recent practice in wireless is discussed and a good sense of perspective is maintained throughout. Occasionally the author allows himself to look ahead and to express opinions on the probable lines of future advance and for this reason the book is one which will appeal to "specialist wireless engineers" although, as stated previously, it is not primarily intended for them. As is natural, detailed descriptions of instruments and machinery and matters of a purely practical nature occupy but a small proportion of the space. The book is well produced and the repetition of Fig. 45 is an example that might well be generally adopted where an intricate line of argument extends from one page to another. The arrangement of the plates is hardly as convenient as it might have been but was determined no doubt by considerations of the cost of production.

The book opens with a short introduction followed by a chapter on Electromagnetic Waves. The difficulties of this subject are admitted on all hands and perhaps the author is well advised to approach the subject as he has done, but it must be confessed that the earlier parts of this chapter are unconvincing and do little beyond restating the difficulties. The working idea of, at any rate, the plane electromagnetic wave might have been more fully developed. After a chapter on the General Theory of Oscillatory Circuits, the Spark, Alternator and Arc methods of generating oscillatory currents are described in a readable chapter that contains the essentials of the respective methods without going into excessive detail. The fifth chapter deals with methods of detecting small oscillatory currents, after which the author can no longer restrain himself but plunges into his main theme, viz. the Thermionic Tube. An excellent description of the two and three-electrode valves is followed by a chapter on Amplifiers, the opening of which seems a little unnecessarily abrupt and is unfortunately marred by a wrong page reference. The principles and uses of the various types of valve amplifier are well described, but the all-important effects of "reaction" are relegated to a later chapter. The next chapter treats of the valve as a rectifier of small currents purely in connection with the reception of signals. The use of the "Triode as an Oscillation Generator" follows in Chapter IX., which appears to fall somewhat below the standard of those preceding it. The "simplified case"

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dealt with in the first instance is really of little assistance and, if anything, makes more difficult the understanding of the actual conditions. The discussion of the limits of amplitude of the oscillation is not easy to follow, and it is unfortunate that the family of $I_a - V_g$ curves is chosen for this purpose instead of the $V_a - V_g$ constant current contours. With the aid of the latter this apparently rather difficult question becomes quite clear. The chapter ends with a short account of the circuits as used for transmitting purposes, including a brief mention of high-power rectifiers. The use of "reaction" naturally follows, and its application in receiving circuits and amplifiers is clearly described. A good account of Wireless Telephony is then given, but the differences between wireless telephony and telegraphy are perhaps rather over-accentuated. The last chapter is a miscellaneous one, and after discussing the need of devising some means of overcoming atmospheric interference the author says, "When the fight against atmospherics has been won . . . π times the radius of a well-ordered world will be the *maximum* range of the stations on it"—a statement with which no one will quarrel!

C. L. FORTESCUE.

Books Received.

THE ELECTRICAL TRANSMISSION OF PHOTOGRAPHS. By Marcus J. Martin. (London: *Sir Isaac Pitman & Sons, Ltd.* 1921. 7″ × 4½″. Pp. vi + 136. Price 6*s.* net.)

THE "PRACTICAL ENGINEER" ELECTRICAL POCKET BOOK AND DIARY, 1921. (London: *The Technical Publishing Co., Ltd.* 1921. 5¼″ × 3¼″. Pp. ciii + 610 + 48. Price 2*s.* 6*d.* net. Post free 3*s.* Abroad 3*s.*)

ARITHMETIC OF TELEGRAPHY AND TELEPHONY. By T. E. Herbert, A.M.I.E.E., and R. G. de Wardt. (London: *Sir Isaac Pitman & Sons, Ltd.* 1921. 7″ × 4½″. Pp. vii + 187. Price 5*s.* net.)

RELATIVITY AND THE ELECTRON THEORY. By E. Cunningham. (London: *Longmans, Green & Co.* 1921. 8¾″ × 5¾″. Pp. vii + 148. Price 10*s.* 6*d.* net.)

Correspondence.

ARC *VERSUS* ALTERNATOR FOR HIGH POWER WORK.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—The author has much to say upon the defects of the arc, but nothing at all to say upon the defects of the H.F. alternator.

The compensation method of signalling has been almost exclusively used in the past, but recently a considerable amount of work has been done upon the suppression of the compensation wave and the emission of a single wave. The problem is not insoluble and has not been seriously attacked sooner because there has been no call for it, due to the small number of high-power stations in operation. One of the needs of the future is the speeding up of transmission in order that a given station will occupy the ether for a lesser time interval. The change of antenna current from maximum to zero at a high rate will probably cause more interference than the small change of wavelength which it is now possible to use, when transmitting from arc stations to stations with good receivers. The small difference between the compensation and telegraph wavelengths from the arc station at Rome should be noted, and this station handles a minimum of 10,000 words per diem of commercial traffic to Bucharest, Constantinople, Massowa, Sweden, England and America.

The necessity of cleaning the arc chamber is true to a certain extent, but it has not been found necessary heretofore to supply three arcs for this reason. Attention may also be drawn to a statement contained in the Report of the Imperial Wireless Telegraphy Committee, 1919—20: "Any good working electrician can run an arc; a skilled engineer must be in charge of a high-frequency alternator."

Aerial insulators are now available to take care of the maximum aerial voltages with an ample factor of safety.

Large arc installations are readily made to give an efficiency of 48 per cent. The auxiliaries are practically *nil*, whereas alternators call for vacuum and oil pumps, etc.

The absence of moving parts in an arc generator and the ability to change any part, which

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might prove defective, within the space of an hour or less contrasts favourably with the days and weeks which must elapse in order to repair a large high-power high-frequency alternator, especially when considering installations in the remote tropics.

Upwards of 20,000 kW of arc generators are now doing good service in various parts of the world, and if questions of first cost and upkeep are carefully studied the arc generator is still able to hold its own.

C. F. ELWELL.

London.
April 13th, 1921.

ARC *VERSUS* ALTERNATOR FOR HIGH POWER WORK.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—The author's suggestion that the arc is becoming obsolete as a high-frequency generator for use in wireless telegraphy hardly gives a just idea of the situation. The alternator is still comparatively in an experimental stage and has yet to prove its practical worth, particularly for work in the colonies. No doubt improvements are to be expected in the future.

High-power arc transmitters have been in regular service for five to six years. During this period considerable improvements have been made in their design and are still going on. Harmonics are being avoided by use of suitable field strength and by the provision of absorption circuits. Suitable aerial constants contribute also considerably to the reduction of harmonics.

The sooting which occurs with illuminating gas, or kerosene, is greatly reduced when alcohol, evaporated in a suitable vaporiser, is employed.

The use of the spacing wave, the length of which differs from the signalling wave by less than 1 per cent. and not 2—3 per cent., is not such a serious disadvantage as the author suggests, and it is by no means certain that the International Conference will suppress it. It necessitates the use by a station of a wider (by 1 per cent.) band of allocated wavelengths, but arc transmission without spacing wave is being experimented with for higher powers, and the problem is not of a kind which is insoluble. If these costly experiments were delayed in the past, it was because the number of high-power stations was not great enough to render this problem really important.

At present, as in the past, the arc is the most reliable H.F. generator. It does not require highly trained attendance, as the H.F. alternator. It is robust, and there is not the risk of serious breakdown, which in the case of an alternator may put the machine out of action for weeks or months.

Two arcs ensure a regular uninterrupted service. It is doubtful whether as much can be said for the H.F. alternator.

One very important advantage of the arc over the alternator is the wide range of wavelengths (from 1 to 4). If suitable field strengths be used the reduction of power for the shorter wavelengths is not very large.

As to the exceptional excess voltages due to the irregularities of the arc, it is to be noted that, although the voltage across the arc may be irregular, the same does not occur as regards the voltage across the aerial insulators, and no greater insulator trouble is experienced with the arc than with the alternator for the same aerial currents.

The above remarks are based on actual working experience with 200 and 450 kW arc generators.

J. MAMLOK.

London.
April 13th, 1921.

A METHOD OF DIRECTION FINDING.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—With reference to Major Erskine-Murray's letter in your last issue.

Ruskin complained of the impossibility of writing even the plainest English that could not be misconstrued; careful statement sometimes fails simply by loss of the over-emphasis, to

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which journalism has accustomed us. I trust that my article did not convey to other readers that I rated "convenience or accuracy" of no account in practical work. A thing may be secondary, that is, derived, or dependent, without being unimportant. For instance, whether you eat your lunch or not is a primary fact; whether you digest it is a secondary one, but failure in the latter sphere of human activity may be more distressing than failure in the former!

The term "secondary considerations" was seriously and accurately meant. The primary fact is the mathematical nature of the curve of the simple loop; convenience (for instance, the preferred use of a comparatively narrow angular swing reading, passing through silence, to a wider swing passing through louder sound) and accuracy (for instance, the preferred use of a rapidly changing portion of the curve) are derived or resulting things—not unimportant, but still derived or secondary. Major Erskine-Murray rather misquotes me by omitting the context, and also the complementary words ". . . this constant signal *within the limits of searching* . . ."

Priority of results does not really enter into the question. During 1917, before the formation of the amalgamated Air Force, it was definitely decided at one of the joint meetings, to avoid overlapping, to leave the development of D.F. in aeroplanes to the R.N.A.S. (who were specialising in Captain Robinson's method) and wireless telephony in aeroplanes to the R.A.F. (who had originated it). It is not surprising, therefore, that the earliest results were got by the only workers in the field thus left open to them, by the only system which they were practising.

No undue stress was intended to be laid on the patents mentioned. Major Erskine-Murray is right in pointing out that they suffer from the fundamental defect of "4 degrees of ambiguity," exactly as does the Robinson system; but is he content thus to dismiss the latter, under the same condemnation?

The substitution of switching for rotation, as in Captain Round's method mentioned on p. 698, was an old device of D.F. experimenters long ere Captain Robinson's ingenious application of it.

I do not think it is a just inference from Captain Round's I.E.E. paper, that a "formidable train of errors" arises from the "more complicated" Bellini circuits.

I find it difficult to analyse my opponent's persistent scorn of the "minimum method." My whole argument was that both the contrasted systems employed a (why "rough"?) comparison of signal strength on each side of the minimum, but in different ways. Both use the minimum; why kick the poor thing when it's at zero?

In conclusion, my critique was not an attack on Captain Robinson's method, but was an attempt to remove certain current misconceptions about it and to set it in its due perspective with respect to earlier and other work. I think that the careful and unbiassed reader of the inventor's exposition, taken in conjunction with my critique, should be in a good position to form a balanced judgment of its place in this special field of radio work, and of what it holds both of good and bad, and perhaps it would be best to allow the articles to speak for themselves, until experiment reveals new facts, or throws some new light on this portion of a most interesting subject.

C. E. PRINCE.

Burchett's Green, Berks.
April 6th, 1921.

THE HETERODYNE METHOD OF WIRELESS RECEPTION, ITS ADVANTAGES, AND ITS FUTURE.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—Mr. Round may well rest assured that the objections he raises have occurred to myself.

I knew from experiments that I have made myself that acoustic resonance gives no appreciable results against atmospherics in the case of reception of damped waves emitted by a musical spark. The reason of it, in my opinion, is that the so-called musical spark, in reality, does not give in the receiving circuit a low-frequency current of *a genuinely periodic nature and form.* As a matter of fact, the tone of the received note is with musical spark

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changed by acoustic resonance. In the case of the heterodyne reception of sustained waves, on the contrary, the received current at low frequency is really a periodic current in *which the same waveshape repeats itself* and actual acoustic resonance becomes possible. The use of acoustic resonance allows then the elimination of atmospherics of medium strength to a remarkable degree. I have built tuned low-frequency amplifiers (see my B.P. 130022) which have shown a noteworthy performance as far as elimination of atmospherics is concerned.

Unfortunately when the atmospherics become strong they themselves assume the same musical character as the reception and, generally speaking, no real help from acoustic resonance can then be obtained.

These results of experiments being well established, I believe that, from the theoretical point of view, Mr. Round makes the following mistakes.

(1) In modulated transmission with reception without heterodyne nothing but the atmospherics are received during the intervals. In the heterodyne reception of sustained waves, on the contrary, it is the *resultant* of the heterodyne and the atmospherics which is received and the two things are not, as Mr. Round thinks, exactly the same. The action of the heterodyne on the reception of the atmospherics is such that any oscillating discharge of long duration caused by an atmospheric produces the same note as the sending station itself. Undoubtedly the rapid variations of the intensity of these discharges which take place at audio frequencies and cause corresponding variations in the intensity of the musical note give the latter the characteristics of a noise similar to that produced by the atmospherics without heterodyne, but it is nevertheless true that the heterodyne gives to the atmospherics a musical character which, although not apparent, seriously diminishes the value of low-frequency tuning.

Here is a particularly impressive demonstration of the above reasoning.

A complete heterodyne reception being installed ready to receive a C.W. station and acoustic resonance at low frequency being provided, let us assume that the station is not sending and the atmospherics alone are being listened to. *Every time that the acoustic resonance is adjusted to the musical note that the station is supposed to give with the heterodyne, a remarkable strengthening of the atmospherics is observed.*

It is obvious that if the note were transmitted by the sending station as in the case of modulated transmission the above phenomenon could not occur.

(2) Regarding the claim of Mr. Round that there is no difference between the heterodyne reception and the reception with modulated transmission, the following reasoning shows that Mr. Round is misled by appearances.

When a C.W. station of frequency f_1 is received with a heterodyne of frequency f_2, the reception is naturally tuned to the frequency f_1. On the other hand a sending station transmitting two frequencies f_1 and f_2 which lie close together (modulated transmission) is received by tuning to the *average* frequency $\frac{f_1 + f_2}{2}$.

In the first case the oscillating discharges of the aerial of frequency f_1 can very well give the note $(f_1 - f_2)$ of the sending station.

In the second case the oscillating discharges of frequency $\frac{f_1 + f_2}{2}$ could only give a note of half the pitch $\frac{f_1 - f_2}{2}$.

In concluding, let me make the remark that while the modulation of the transmission for the purpose of reducing the atmospherics has been much discussed in the last few years (Round, Meissner, Lévy, Western Electric Company) the writer has been the first to recommend that this modulation be carried on at low frequency according to already known diagrams *and not at high or inaudible frequencies.* In addition when heterodyne reception with low-frequency tuning is used and the frequency of transmission is perfectly constant, it is preferable to tune the reception to a low pitch note as explained in my article.

MARIUS LATOUR.

Paris.

April 8th, 1921.

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THE RADIO REVIEW

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PROFESSOR G. W. O. HOWE, D.Sc., M.I.E.E.
Assistant Editor:
PHILIP R. COURSEY, B.Sc., F.Inst.P., A.M.I.E.E.

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F. HARMS

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THE

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THE
RADIO REVIEW

VOL. II JUNE, 1921 NO. 6

Editorial.

Earth Aerials.—One of the most surprising features of the war was the long-sustained resistance of the enemy forces in German East Africa. Considerable light is thrown upon one aspect of the campaign by the publication in the current number of *Telegraphen- und Fernsprech-Technik* of an article entitled "Earth Antennæ and their Use in German East Africa." The author was in charge of the wireless station at Dar-es-salam, which possessed an umbrella aerial 100 metres high. This was demolished, however, on August 8th, 1914. Although this prevented further long distance transmission, it actually improved the reception of signals, as it forced the author to experiment with long earth antennæ, with which better results were obtained than with the umbrella aerial. The signals from Nauen had always been so weak as to be almost unreadable. On the night of July 31st, Kamina (Togoland) commenced to transmit, and thus kept Dar-es-salam informed of the progress of events until it fell in September. Windhuk, in German South-West Africa, was first heard at Dar-es-salam on August 2nd, and transmitted information until its capture in May, 1916. By this time, however, East Africa was almost independent of African transmitting stations, because properly adjusted earth antennæ and the introduction of amplifiers led to such improved signals that Nauen could be received directly. Special listening posts equipped with earth antennæ received the messages from Zanzibar, Congo, Massowah, Durban, and the principal military stations of the Allied forces. The information thus received played a large part in the German success in evading the encompassing forces. The aerials employed consisted apparently of a wire suspended at a short distance above the earth. In some cases the wire was connected to earth at one end through the coil of the receiving apparatus, the tuning being done by means of a condenser placed in series or in parallel with the coil. When the length of the wire was about a quarter of the wavelength it was found that this arrangement, contrary to expectations, had very little directive effect, but received signals from Nauen when broadside on to the direction as good as those received on the large umbrella aerial. Better results were obtained on lengthening the wire until one of its harmonics corresponded to the received wave; this not only gave stronger signals but gave the system a pronounced directive effect, the signals being strongest, of course, when the wire was in the direction of the transmitting station. The receiving apparatus may be inserted in the wire at a potential node without any connection to earth. If it is inconvenient to lengthen the wire it may be arranged as a fork or side wires can be run

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out at right angles to it to increase its collecting power. It was found possible to prevent interference between signals of the same wavelength from stations separated by fifteen degrees by running out two separate wires in the directions of the transmitting stations, and making them so long that the third harmonic was set up. Such directive action not only cuts out disturbing stations but also reduces interference due to atmospherics. The subject of earth aerials is one which requires systematic investigation, and one must admire the contribution made to the subject by the German wireless engineers under such great difficulties.

Directional Measurements with the R.A.F. System.*

By J. HOLLINGWORTH, M.A.

I. INTRODUCTORY.

The R.A.F. system of W/T directional measurements is now sufficiently well known to make a detailed description unnecessary.

It has been fully treated as far as war-time developments are concerned by the inventor, Captain J. Robinson, R.A.F.,† and the present paper is in a sense a supplement to this. That such a further development is necessary, is clear from the conditions of the case. Being entirely a war-time product the primary need was its practical application ; it was not possible to investigate it scientifically. At the same time it is this stage of its development with which most of those who can claim any practical experience with the system are acquainted ; with the result that its capabilities and limitations are not fully understood. To investigate these in fuller detail has been the object of this paper ; and to see what results could be expected with proper care in the design. This may in some cases have resulted in a considerable departure from the original ideas and methods of the paper referred to above ; but this is inevitable in any subject while in process of development.

At the commencement a short historical note will not be out of place. The system was invented during the war for use in aeroplanes, which is of course a very specialised application, with its own set of conditions. For instance, in the small aeroplanes to which it was originally applied, the primary need was a loud signal in order to overcome the various engine noises. Accuracy was a secondary consideration as with such small machines, except on a very calm day, the pilot could not hold the machine sufficiently steady to make an accurate reading possible. Later it was applied to larger machines ; but for many reasons its full capabilities were not investigated at the moment. At the time of its invention in 1917 the need for some such system was extremely

* Received November 24th, 1920.

† Paper read before Section G of the British Association, 1919—see RADIO REVIEW, I, pp. 39—42, October, 1919, for abstract ; also pp. 213—219, February, 1920, and pp. 265—275, March, 1920, for fuller description.

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urgent. As soon as it was found to be practicable it had to be brought into use; there was not time to investigate the many points of minor importance which always arise in a new system. Production and experiment had to go on simultaneously; with the result that none but minor modifications could be introduced without upsetting the production.

Also during this period there were generally not more than two experimenters at work on the subject; and all their time was taken up with the mechanical question of installation in new types of machines and the overcoming of the more obvious troubles and difficulties which presented themselves. Naturally under these conditions detail work was out of the question; many interesting points were, as a matter of fact, noted and deliberately put aside for consideration in less strenuous times.

There was no general body of experience to guide the investigators, they had to rely, both in theory and application, almost entirely on their own personal experiences.

It is not of course claimed that the results are in any way complete even yet, there are still applications and conditions which have not yet been touched.

II. GENERAL DETAILS OF THE SYSTEM.

(*a*) *Constructional.*

The set on which most of the work in the paper has been carried out is home-made. It consists of a wooden stand about 6 feet high and 6 feet long with a cross-bar about 2 feet from the floor carrying the lower bearing. Being intended for general experimental work, it is constructed to give as much flexibility as possible. In most coil sets the bearings are connected directly to the coil frames, but in this set they are fastened to two wooden platforms each 1 foot square; the upper one being adjustable for height. The coils are fastened to these platforms by means of thumbscrews so that any coil system, within certain size limits, can rapidly be fixed in position. This gives great freedom for experimental work, but only at a sacrifice of a certain amount of mechanical accuracy and rigidity. It was not expected when the coil was built that such a high sensitivity would be reached as has been actually obtained, so that now it is seen that sturdier construction would have been advisable. It was originally designed for the purpose of investigating the well-known temporary variations in the directions of W/T signals and for this purpose it was hoped to reach an accuracy of about 1°. With careful handling however the set can be worked to ¼°.

The leads to the coil are carried through the lower spindle, which is hollow, and then cleated to the frame; the necessary gear being fastened to one of the upright sides. The coils are of box form, the main coil (adopting the usual notation) being 3 feet 6 inches square, the auxiliary 5 feet 6 inches long and 3 feet 6 inches high. Theoretically there is an electrical difference between coils of different patterns but when the set was built this was left for later consideration.*

* A. S. Blatterman, *Journal of the Franklin Institute*, 188, pp. 289—362, September, 1919—RADIO REVIEW Abstract No. 144, January, 1920.

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As at present arranged the set works over a wavelength of 2,000—15,000 metres, and with a home-made amplifier a sensitivity of $\frac{1}{4}°$, representing a movement of about $\frac{1}{7}$ inch of the outside edge of the coil, can be obtained. (To avoid confusion in the later part of the paper it is necessary to draw a definite distinction in the use of the words "sensitivity" and "accuracy." A sensitivity of say $\frac{1}{4}°$ will invariably mean that if a balance be obtained and the coil frame then shifted $\frac{1}{4}°$ the signals on reversal will be audibly out of balance. It has no direct connection with accuracy of direction, which will mean that the direction obtained is the true direction, of the incoming waves. It is thus often possible to have high sensitivity together with low accuracy.)

Two great points that can be urged in favour of the system are simplicity and portability.

The set referred to throughout this paper is self-contained in a wooden frame about 6 feet high and 6 feet long. Excluding the amplifier and its accessories the entire gear weighs about 40 lbs., and could probably be constructed for £10 to £20. The whole apparatus could be put on a truck, taken to a new place, and, with the help of a compass or point of sight to obtain correct orientation, would be ready to take bearings a few minutes after its arrival. It requires no outside connections and can be used in any room reasonably free from metal work which might cause distortion. For special and more permanent purposes coils have sometimes been mounted above the roof of a special hut and rotated by gear from inside. On the electrical side it contains only one tuned circuit, accurate tuning of which is unessential except in very special cases.

(*b*) *Operational.*

The actual direction, as is well known, is obtained by finding the point at which the signal strength is unaltered on reversing the connections of one of the two coils. It is thus a definite point and does not require the taking of the mean between two positions. This is especially useful when watching for variations on a particular station, as it is not necessary in this case to be continually taking fresh readings. The set is balanced on the station at the start, and then all that is necessary is an occasional movement of the reversing switch. As long as the signals still remain of equal intensity there is no necessity for any further movement of the coil, and the bearing is known not to have changed; but as soon as a variation is noticed, the coil is shifted to the new position, giving at once the change of direction which has occurred.

One of the objections which is most frequently brought against the system is what is known as the 90° ambiguity; that is, that it is theoretically possible to obtain a balance of signal strength at a position exactly 90° away from the true bearing. Cases of this have undoubtedly happened. With the original coils and apparatus it was much easier than it is now; and most of the causes of such error which did occur were with partly trained operators on one of their early flights.

Under such conditions errors are bound to arise, but with a better designed coil it is far more difficult to obtain a wrong bearing than a correct one.

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As this is a point of great importance it really needs to be discussed in more detail. The original standardised way of eliminating this error was by the use of what was known as a balancing coil. By moving a switch the auxiliary coil is cut out and replaced by a small coil of the same inductance which is supposed to pick up no energy. A rough maximum is then found, the auxiliary coil is switched back, and balancing proceeds in the usual manner. This worked moderately well when the two coils were of nearly equal size, and if they are exactly the same size it is essential. Now however the tendency is to make the auxiliary coil considerably larger than the main coil (the question of the exact ratio will be considered later), and as this difference in size increases, the difficulty of obtaining the true bearing by this method grows very rapidly. The reason is as follows. The preliminary search is for a maximum signal; and owing to the well-known flatness of such maxima it is often impossible to be sure of getting an accuracy of more than 10° at the best. Now with a large auxiliary coil it does not take a deflection of many degrees from its zero position to produce in it an E.M.F. actually greater than the E.M.F. in the main coil. So that when an approximate maximum is found and the auxiliary coil switched back, it may introduce into the circuit an E.M.F. greater than the one in the main coil. Under these conditions reversal produces quite abnormal effects. Moving the coil frame in one direction (the direction which tends to reduce the auxiliary coil E.M.F.) results in a decrease of signal strength for both positions of the reversing switch, the weaker one falling rapidly to zero, the other more slowly. Operators do not understand that if this happens they must pass through the position in which one signal is zero; as soon as they find the difference between the signal strengths getting greater they start moving the coil in the opposite direction. Movement in this other direction causes an increase for both positions of the reversing switch, though the difference between the two signal strengths decreases owing to the E.M.F. of the main coil becoming negligible compared with that in the auxiliary coil, which occurs at or near the 90° error bearing. So that if, owing to the flatness of the maximum signal, the approximate bearing first selected is more than a few degrees separated from the true bearing, this method of search actually leads directly to the 90° error unless the operator has a sufficient theoretical understanding of the method to grasp what has happened. But by adopting a slightly different method of search this trouble is entirely eliminated. The very conditions which cause a decrease in the case of working the first method increase the certainty of this second method, which only fails when the two coils are exactly equal. It has been pointed out that this is never the case with a modern coil set. Also this method requires no balancing coil or switch. The following are the operations required:—

(1) Put the reversing switch to one side and find very roughly the minimum position (unlike the previous method an error of 5° is quite unimportant).
(2) Move over the reversing switch, the signal will increase in strength.
(3) Find roughly the new minimum position *nearest to the old one.* In coils with modern ratios there will be no ambiguity here, these zeros are 15°—20° apart whereas the wrong zero is of course 70°—75° away. If necessary, however, (3) can be written in another form which is perfectly definite by saying:—

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Turn the coil in the direction which causes a decrease in signal strength until the new zero is reached.

(4) The true position is between these two zeros and is found in the usual way.

This method is invariably used by the author, and by several operators who thoroughly understand the system and have deduced it for themselves. It is just as quick as the old method and far easier to work in coils of normal ratios. It also eliminates a trouble sometimes present in the old method, that on powerful stations the pick-up of the balancing coil and its leads was not negligible, which flattened the maximum even more. In actual working the whole operation can be picked up in two minutes by anybody of average intelligence, and once grasped it becomes automatic in a very short time. Of course in coils constructed for an abnormally high sensitivity it requires more care, but this is a fact which holds equally truly for any physical measurement of any sort whatever; unskilled observers can never get results of high accuracy.

III. ERRORS.

Some attention must now be given to the errors which are likely to arise in any D.F. system. These can be divided into two classes: (*a*) amplifier and reactive troubles, (*b*) extraneous E.M.F.'s induced in various parts of the circuit.

(*a*) When this set was first constructed trouble was experienced with the amplifier. This was a home-made resistance type amplifier with six valves. It showed considerable tendency to oscillate unless its amplifying power was kept low, and, what was more serious, movements of the operator when reaching out to turn the coils altered the capacity distribution sufficiently to shift the apparent bearing 2°, and often to set the amplifier oscillating. This was probably largely due to the design of the amplifier, but it was cured by fitting a two-valve note amplifier, and by inserting a radio frequency transformer between the coil and the amplifier, so that the leads to the amplifier no longer formed part of the tuned circuit, and also a transformer in the telephone circuit. A resistance amplifier was adopted intentionally, as it had previously been found that with the transformer amplifier on a table close to the coil, radiation from the transformers into the coils upset the readings, especially on wavelengths near the natural frequency of the amplifier transformers, which is generally the point at which such amplifiers are intended to work. This could no doubt be cured either by shielding the transformers or by having the coils on the roof at some distance from the amplifier, but where simplicity and portability are required a resistance amplifier seems to be the simplest solution.

(*b*) Extraneous E.M.F.'s are caused either by small E.M.F.'s induced in the leads of the coil circuits or any subsidiary circuits which may exist (especially if the latter have any tendency to a natural frequency near the working frequency); by what is known as "vertical" or "antenna" effect, the whole system acting as a capacity to earth; or by the effect of certain

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factors depending on the size and shape of the coils. Theoretically they may be divided into two classes according as to whether they are in phase with the working E.M.F. or 90° out of phase with it, and it is therefore sufficient to consider these two cases only.

(i.) E.M.F.'s in phase with the signal. Provided such E.M.F.'s do not reverse with the operation of the reversing switch, which means that the leads from the coil under reversal must receive special attention, the only effect of such "pick-ups" is to cause a slight alteration in the apparent strength of the main coil. They have in this case no effect on the directional accuracy. In a pure minimum system such E.M.F.'s of course produce a false zero, the coil has to be displaced until an E.M.F. is induced in it to exactly counterbalance the disturbing E.M.F. They are also extremely difficult to detect.

(ii.) E.M.F.'s 90° out of phase with the signal. The effect of E.M.F.'s 90° out of phase, is, as is well known, to blunt the minimum effect, so that for accurate work on a minimum method special care has to be taken to eliminate them. In the R.A.F. system it will now be shown that unless they are abnormally large the difference they make in sensitivity is negligible.

Consider for simplicity displacements of 5° on either side of the zero position of the auxiliary coil, over this range the E.M.F. induced in this coil may be taken as proportional to the angle of displacement. In Fig. 1 let the vector 0A represent the E.M.F. at a displacement of $-5°$; then 0A′ represents the E.M.F. at $+5°$, intermediate lengths representing the E.M.F.'s at the corresponding intermediate angles. Now any such 90° E.M.F. which may be present will be represented by a constant vector 0C at right angles to 0A; so that the total E.M.F. at $-5°$ is given by the vector CA, at $+5°$ by CA′ and similarly at other points. The resulting signal strength merely depends on the length of these vectors and not on their sense, so that it may be shown in a more convenient form as in Fig. 2. In this figure the abscissæ are as in Fig. 1 the angular displacements of the coil.

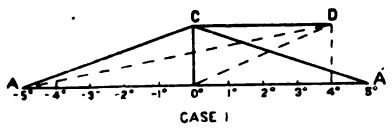

FIG. 1 (*a*).

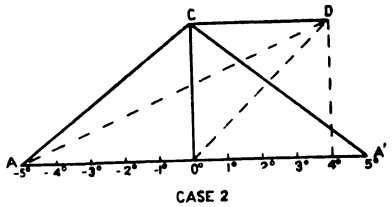

FIG. 1 (*b*).

The ordinates are the appropriate signal strengths, *i.e.* the ordinate at $-5°$ in Fig. 2 is equal in length to CA, at 0° to C0, at $+5°$ to CA′. In this way a curve is constructed giving the magnitudes of the E.M.F.'s induced in the coil system at various angular positions; and so, neglecting the amplifier factor, giving the signal strengths of these positions.

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This curve has been constructed for two cases.

(1) Small vertical effect, producing an E.M.F. equal in magnitude to the displacement of the coil through 1°. (Curve B.)
(2) Large vertical effect four times as great as in case (1). (Curve A.)

These two curves give therefore the E.M.F.'s of the coil in the neighbourhood of its minimum position and show the extreme flattening of the minimum especially in case (2). Now, returning to Fig. 1, consider the case of the R.A.F. system. The addition of the main coil will produce a third E.M.F. in the circuit. This E.M.F. will be practically constant over the range considered, since the main coil is in its maximum position and will be in phase with 0A, it can therefore be represented by a vector CD of constant length parallel to AA'. The E.M.F.'s induced in the coil system will now be, for the various displacements, given by DA, D0, DA', instead of CA, C0, CA' as previously.

These have been plotted in Fig. 2 in the same way as for the minimum coil. It will be seen that in both the minimum and the R.A.F. systems the slope of the curve at 0° is a measure of the sensitivity of the system considered. (Curves C and D.)

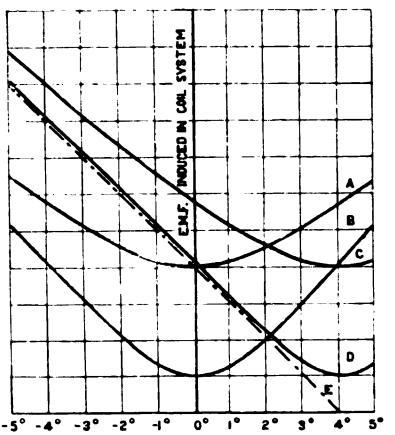

FIG. 2.

This is obvious in the ordinary method and in the R.A.F. method it follows from the fact that owing to the symmetry of the vector diagram the curves obtained in Fig. 2 on reversal are the images in the y axis of those obtained before reversal. For the purpose of comparison another curve has been plotted in Fig. 2 for the case of the R.A.F. system when the vertical effect C0 is zero. (Curve E.)

Now on examining the curves for the R.A.F. system at the 0° position it will at once be seen that the effect on the slope of the curves at this point, even when considerable vertical effect is present, is quite small, whereas the effect on the corresponding cases for the minimum coil is considerable. Moreover the value taken for the main coil E.M.F., CD in Fig. 1, is probably smaller than that actually used, and from the diagrams it follows by inspection that the larger CD is in comparison with C0, the smaller the departure from the ideal case due to antenna effect. Hence the R.A.F. system is only slightly affected in sensitivity by the presence of such extraneous E.M.F.'s and no special adjustable compensating devices are required to eliminate them.

The question has now to be discussed as to where in the circuit such E.M.F.'s are likely to occur: their phase relations and the methods of

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detecting and eliminating them. They may be expected in more or less degree in the following places :—

(I.) Pure " coil effects " (*i.e.* in phase with the signal) in the leads and connections of the main coil.
(II.) Ditto in the leads and connections of the auxiliary coil.
(III.) Pure " vertical " or " antenna " effects in these coils.
(IV.) E.M.F.'s induced directly in the primary or secondary windings of the radio-frequency transformer.
(V.) Coil shape effects.
(VI.) Re-radiation from the transformer into the revolving system and *vice versâ*.
(VII.) Re-radiation from the amplifier.
(VIII.) Variable capacity effects.

Each of these has to a large extent its own distinctive symptoms and effects, and requires its special cure. (It will be assumed at present that the auxiliary coil is the one which undergoes reversal.)

Errors (I.) have no effect on the directional accuracy, they merely cause a slight change in the apparent strength of the signal. They do not need therefore further discussion. (II.) Owing to their occurrence in the part of the circuit which undergoes reversal these E.M.F.'s cause a definite error in the directional accuracy. As however the only part of the system in which they can possibly occur is in the leads between the terminals of the coil undergoing reversal and the reversing switch, these leads should be as short and as close together as possible. By mounting the reversing switch on the coil frame they can be entirely eliminated, but in general it is hardly necessary to do this.

Unlike certain other errors they do not cause any 180° inaccuracy, that is if a bearing be taken with the coils turned round it is exactly 180° from the original bearing. This makes them extremely difficult to detect and the following procedure has been adopted which, though not absolutely proving their absence, makes it likely. The bearing and reversed bearing are taken, and if no other errors are present they should be exactly 180° apart. (For this purpose it is best to work on a wavelength near the upper limit of the set.) The connections are now changed so that the main coil undergoes reversal and the two bearings again taken. If the bearings now obtained are different from the previous ones but retain their 180° accuracy it means that the pick-up in the main coil leads is different to that in the auxiliary coil leads. But if they are the same it means that these two pick-ups are exactly equal which is unlikely since they come from different parts of the circuit which can be arranged in different positions on the frame. It is then assumed, though the proof is not absolute, that these pick-ups are negligible.

Though affecting the absolute accuracy they do not affect the sensitivity.

(III.) " Vertical " effect is in general 90° out of phase with the signal E.M.F. and is practically independent of the orientation of the coils. It produces a flattening of the minimum, and in some cases affects the 180° accuracy of the reversed bearing which will be dealt with later. It has already been shown

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that the first of these, unless excessive, has very little effect on the R.A.F. system. In general it is probably much less in the case of a coil of small dimensions than with a large aerial: Blatterman * states that it is roughly proportional to the height of the coil. Various methods have been suggested for eliminating it if necessary but some of them are rather complex and in the case of the R.A.F. system its effect is probably negligible for sensitivities of $\frac{1}{2}°$ and over, especially if, as suggested by Captain Round, † the tuning condenser is not of too small a value. Any appreciable errors with this phase relation which occur probably come from other parts of the system.

(IV.) These errors are due to the presence of the transformer and it would seem that the easiest way of eliminating them would be to omit it. This brings in still worse errors. If it is not there the leads to the amplifier form part of the tuned circuit, and consequently pick up E.M.F.'s far more easily than they would do if untuned. It must not be forgotten that though the main tuning inductance of an oscillating circuit may be completely shielded, small leads in that circuit have a picking-up effect out of proportion to their actual size compared with what they would have in an untuned circuit. Also it brings the coil windings into direct metallic connection with the amplifier circuits, and so through the telephones with the operator, so that any movements of his tend to vary the capacity of the system to earth to a serious extent.

It also eliminates a trouble frequently found in the early sets that momentary bad contacts in the switch during reversal caused loud crashes and howls in the amplifier due to isolation of the grid of the first valve. This interferes with the judgment of signal strength.

E.M.F.'s induced in the primary of the transformer are in phase with the main E.M.F. and as this is a non-reversing part of the circuit they are similar to those in case (I.) and can be neglected. But if induced in the secondary winding it can be seen from a study of the phase relations that they produce a current 90° out of phase with the signal current and thus produce the same results as "vertical error." As in that case if small they can be neglected, but to guard against any danger it is well to design the transformer so that its natural wavelength when connected to the amplifier is well below the lowest wavelength to be used.

This is not difficult if the required wavelength range is small, but if a large range is required it is not easy to get a transformer with a sufficiently high natural frequency which will at the same time transfer sufficient energy at lower frequencies. (V.) and (VI.) produce similar very distinctive effects, and it was some time before their cause was suspected. (VI.) is of course more prominent when the direction of the station is such with regard to the frame that one side of one of the coils is near the transformer. In the case where the effects were most observed the transformer was unsatisfactory owing to its natural wavelength being too long so that the effect of (VI.) was

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* *Loc. cit.*

† H. J. Round. Direction and Position Finding. (*Journal of the Institution of Electrical Engineers*, 58, pp. 224—257, March, 1920.)

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large compared with that of (V.) and with a more suitable transformer the effect was reduced, but except in special cases it still remains owing to (V.). In the case observed the auxiliary coil was nearer the transformer and if reversal were made on the auxiliary coil, of the two minima referred to on p. 285, one was extremely blunt, and the other sharp; the same holding for the reversed (180°) bearings. If however the reversal were made on the main coil, one pair of minima were very sharp, the other pair very blunt.

Now both (V.) and (VI.) can be shown to produce this effect. (V.) is caused by currents passing through the main condenser and then across the coil due to capacity between turns.

The driving E.M.F. of these currents arises from the fact that in a box coil the voltage between successive turns is not zero since these turns are in different planes. "Coil shape" effect thus causes a current which, being untuned, is 90° out of phase with the signal current and it is also directive reaching the maximum in the position where the main signal coil E.M.F. is zero and *vice versâ*. With a pancake coil it is zero always. It thus behaves in the neighbourhood of the true bearing position like a "vertical" effect which is constant for small displacements but which changes sign if the coil be tuned through 180°.

Since the pure "vertical" E.M.F. does not change sign under these conditions and the two are in phase it follows that for one position of the coil the resultant E.M.F. is the sum of these two, but for the 180° position it is the difference.

If therefore these two can be made equal, perfectly sharp zeros will be obtained for one pair and very blunt for the other pair. Either of these pairs will lead to a true bearing provided no other errors are present though of course the sensitivity of the blunt pair will be much lower, it is only important to see that the "coil shape" E.M.F. does not reverse on operating the reversing switch. This can be ensured by always reversing the main coil, since owing to its few turns this current in it must be very small. As regards (VI.) it will be seen that if the auxiliary coil be reversed the relative phases of the E.M.F.'s induced in the secondary of the transformer due to direct inductance from the auxiliary coil and from the primary of the transformer will also be reversed, but this will not occur if reversal is made on the main coil which is so much smaller than the auxiliary coil that its inductive effect can probably be neglected. Hence if a box coil be used of such proportions that the "vertical" E.M.F. is equal to the "coil shape" E.M.F. sharp errors will be obtained. Both these effects diminish rapidly as the wavelength and the main tuning capacity increase.

(VII.) opens up the whole question of the amplifier. There is no doubt that for directional work the ideal for the amplifier is very different to that which is required for ordinary work. In the latter the main object is maximum amplification, subject to reasonable ease in operating. For directional work everything else has to give way to stability. There must be no risk of variations in the amplifier. For this reason any effect involving reactive coupling or critical adjustments must be viewed with the utmost suspicion, and it appears likely that the most suitable form is a resistance

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amplifier with a large number of valves to compensate for their being worked under stable and so relatively inefficient conditions.*

In a transformer amplifier also, there is, as referred to above, the effect of radiation from the transformers into the receiving coils and their own picking-up effect if worked (as they generally are) near to their natural frequency. Such errors may have any phase relations depending on the amplifier connections and adjustments.

(VIII.) has been partially referred to on p. 286; but comes in in another form also. The "vertical" effect has been assumed constant for all positions of the coil. There is no direct evidence on this point and it would be extremely difficult to obtain, but it is well to note that if it does vary (for instance when the coil is close to one of the side frames), the effect would be to cause the curve in the neighbourhood of the zero to be unsymmetrical, so that the true bearings would not be half way between the points of equal intensity. There is however little experimental evidence of such an occurrence so that it is at present fair to assume the zero to be symmetrical.

Effect of Stray E.M.F.'s on Absolute Accuracy.

In the above discussion with the exception of case (II.) the effect of the induced E.M.F.'s considered has been to affect the sensitivity rather than the absolute accuracy. There is much evidence to show that in certain cases the latter is also affected, and some of the assumptions made above require slight revision.

The question of equal intensity of "vertical" E.M.F. for all positions of the coil has already been mentioned, but it has also been assumed that the various circuits have either been exactly tuned or that the currents induced in them have been exactly 90° out of phase with the E.M.F.'s. Now many of these circuits have an appreciable resistance so that the possibility of an intermediate phase angle is always present. Also while the phase relation between incoming wave and "antenna" current is fixed, that between incoming wave and working current depends on the tuning of the main circuit. Thus theoretically it is possible, by varying this tuning, to produce any required phase relation between the "vertical" current and the main current.

Now if from any cause such an E.M.F. produces a component of current in phase with the main current, the effect may come under case (II.) and produce a false bearing. Moreover if the coil be tuned through 180° all the E.M.F.'s with the exception of this E.M.F. will be reversed when there will be produced not only a false bearing but one not at 180° from the other one.

It has been found by actual experiment that by varying the tuning of the main circuit these effects can be sometimes produced. The zero or point of balance can be shifted at will and also it is possible by slight mistuning to find a point where the zero is very sharp. Unfortunately this is by no means necessarily the position of true bearing, it merely shows that any "vertical"

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* C. L. Fortescue. The Design of Multiple-stage Amplifiers using Three-electrode Thermionic Valves. (*Journal of the Institution of Electrical Engineers*, 58, pp. 65—82, January 1920.)

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effect which may be present is practically in phase with the main current and therefore that its disturbing effect on the bearing is maximum.

The above discussion of errors is long, but an attempt has been made to deal fairly fully with their diagnosis and cure. Some of the deductions may be incorrect as it is very often impossible to vary the conditions in just such a way as to give absolute proof. It is rather a case of drawing inferences from a limited number of data available. Generally speaking, elimination of errors seems to be rather a question of careful design than of the use of special devices.

Summarising these results the following precautions appear to be advisable.

(*a*) If possible when working on the lowest point of the wavelength range have a fair value of tuning capacity.

(*b*) Always reverse the main coil.

(*c*) If sharp and blunt minima occur readings taken on the sharp side will be accurate provided they do not vary as the value of the main tuning condenser is shifted.

The "coil shape" effect can be eliminated by using a "pancake" coil; but only at the expense of an increased "vertical" effect. If the box coil can be so arranged that the two balance the results will be satisfactory.

IV. DESIGN.

In the early days of the system coils were of course constructed mostly by guesswork, and in many cases their chief dimensions were fixed by the size of the space available for their reception. More careful study has now made it possible for them to be more truly designed; and, given a free hand in dimensions, it should be possible to construct a coil to a given performance specification. The general lines of such design will now be given.

Coil Sizes.

The early rule was to work from the maximum permissible inductance and divide this between the two coils so as to give a pre-determined ratio between them.

This is the method suggested by Captain Robinson in his paper, but the objection to it is that his constant K has to be arbitrarily determined. This constant, as will be seen later, is a function of coil size as well as of sensitivity required, so that a large amount of experimental information is required in order to determine K for a given accurate value of sensitivity.

With small cramped coils this is still the only possibility; but where more space is available the problem should be treated rather differently. The fundamental quantity is of course "area-turns" of a coil (the summation of the frame area for the number of turns) this being the quantity which determines the E.M.F. induced in it. Now for a given value of area-turns, the smaller the coil frame the larger the inductance, hence in small spaces it is often difficult to get the value of the area-turns sufficiently high without getting near to the safe limit of capacity required to keep the amplifier from oscillating. In this case special care has to be taken to keep down the capacity of leads, etc.

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When space permits it is better not to work to the full limit of inductance available. The question of leads is not then such an important factor and also the set will be much more stable. Longer waves can be obtained by increased capacity, as the efficiency of an amplifier does not fall off very rapidly with increased capacity in the circuit. Quite a good signal has been obtained from **P O Z** on a coil about 3 feet square with 48 jars across its terminals though this was an extreme case.

Naturally a set which is only required to work on a single wavelength can be made much more efficient than one which has to give reasonably good results over a big range, both as regards amplifier and the coils.

When more freedom as regards dimensions is possible, the design of coil size should be tackled as follows.

The area-turns of the main coil determine the signal strength ; those of the auxiliary coil the sensitivity. Hence each should be considered on its merits, bearing in mind that there is a limit to the value of their combined inductance. With coils above a certain size, depending on the wavelength to be received, the inductance of the main coil will not be more than about 10 per cent. of that of the auxiliary coil since the inductance falls off nearly as the square of the number of turns.

Consequently the area-turns of the main coil can be varied within considerable limits without making much alteration to the total inductance, so that the two coils can be designed nearly independently.

The area-turns of the main coil are settled by the required signal strengths on a given station. This of course must be roughly known for the particular amplifier employed. Now if the set is to be sensitive to, say, less than 1°, the area-turns of the auxiliary coil must be of such a value that by a displacement of 1° an E.M.F. will be induced in them sufficient to make an audible change in the signal strength.

The area-turns of both having been thus determined the coil dimensions can be calculated from the inductance available. But this involves a factor which has only recently been made the subject of experiment. The problem may be stated thus :—

(I.) For a given signal strength what is the least change which is distinctly audible ?

(II.) How does the magnitude of this change vary with the original signal strength ?

The answer to this involves three factors, the operator, the telephones and the amplifier. The last is a purely W/T problem, but the first two together form a partly physical and partly physiological problem which can only be answered by experiment.

Such an experiment has therefore been conducted on the following lines. Signals from a buzzer or audio-frequency alternator are passed into a telephone circuit, their strength being directly under control of the listener, who varies the adjustments until a definite change in intensity is audible, when the change is measured electrically.

The difficulty of measuring un-amplified radio-frequency signals to any

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degree of accuracy is sufficient to require a second experiment to itself, and it would only make the experiment described below impossibly complicated; so that it was decided to investigate the factors separately rather than in combination.

In Fig. 3 A is a buzzer or alternator providing the test signals. The working current is controlled by a resistance R of about 40 ohms. This serves two purposes; it regulates the current in the buzzer to its best working value, and also allows the range of test signals to be varied considerably. Shunted across R is a potentiometer P consisting of two barrels each of 37 ω connected in parallel. Each barrel has its separate slider. These sliders are connected to the back and front contacts of the Morse key K. The centre contact of the key is connected to the telephones T and back to one end of the potentiometer. L is a coupling coil by which interference signals from the buzzer A_1 can be introduced if necessary.

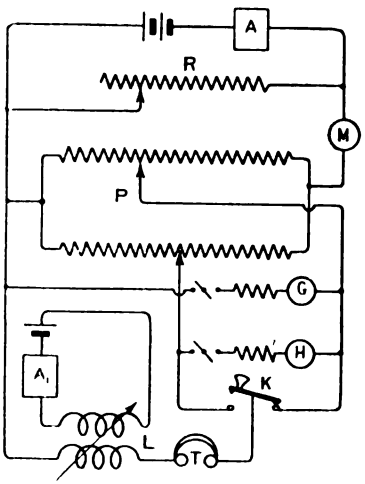

FIG. 3.

The action is as follows: The buzzer A is set working and the current taken by it produces a difference of potential between the terminals of R. This difference of potential also occurs in P, which is across the terminals of R. A sound will then be heard in the telephones whose strength depends on the position of the upper slider. But if the key K be pressed the strength of the sound will be determined by the position of the lower slider.

The upper slider is set to any convenient signal strength, and the listener then operates the key, and moves the lower slider until the least definite difference of signal strength is noticed for the two positions of the key K. H is a microammeter of known resistance with a key, the depression of which gives the difference of voltages between the two sliders. At the same time the potential between the upper slider and the end of the potentiometer is given by depressing the key of the high resistance reflecting galvanometer G. The ratio of the reading of H to the reading of G when multiplied by the instrument constants thus gives the ratio of the difference between the two resistances under the potentiometer sliders to that under the top slider. Now whatever be the relation between the current and the signal strength, if one assumes that the pulsating current giving the signal is proportional to the displacement of the potentiometer slider, this ratio of H to G is the ratio between the increment of signal strength and the original signal strength. This assumption is probably true since a potentiometer "divides" alternating current in the same ratio as continuous current so long as the end effect of the inductance formed by potentiometer barrel is negligible, or the inductive effect is negligible compared with the resistance effect.

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The readings of G are comparative values of signal strengths, provided that the buzzer does not vary appreciably during the test. To ensure this as far as possible a buzzer which gives an extremely steady note is used, and also a milliammeter is placed at M, and readings only taken when this is steady at a definite value. Even when using the alternator the battery is retained in order to operate the galvanometer, its function then being merely to provide the necessary C.C. potential difference for the resistance measurements. It has no direct influence on the signal which in turn has no direct effect on the galvanometers whose moving parts have high moments of inertia. To obtain a comparison between tests at different times, at some time during the test the top slider is moved to the extreme left and a bottom slider adjusted until a just audible signal is obtained. The ammeter H then gives the volts drop corresponding to a just audible signal. This was of course a very rough comparison, and did not give very satisfactory results owing to slight leakages of signal current; with the present arrangement it is not possible to use a shunted telephone method owing to the disturbance which would be caused in the voltage distribution by such shunting. To employ this a telephone transformer would have to be used, but fortunately, as will be seen later, the results come in such a form that accurate comparison is not essential.

The telephones at present being used for the test have a total resistance of 5,600 ohms so that their shunting effect on the potentiometer is negligible. For low resistance telephones the transformer would again be required. The instruments H and G only take a few microamperes each and as the current in M is of the order of 10 milliamperes their shunting effect can also be disregarded.

The results obtained are exceedingly interesting but require careful consideration. Many factors such as fatigue, external noises, and the psychological factor of self-deception come in, so that a certain number of readings obtained are bound to be abnormal. Moreover H measures a small difference in voltage to a high degree of accuracy, far higher indeed than the ear can detect, so that quite large variations in H are bound to occur. The apparatus is intentionally arranged so that it is almost impossible for the observer to adjust his results either consciously or unconsciously to the desired value. During the actual determination of the slider position neither galvanometer is reading, and even after their readings have been obtained they indicate little until various arithmetical operations have been carried out on them.

The first series of tests were taken in a moderately quiet laboratory without interference from the buzzer A_1; and the range of signals was from practically inaudible to about "R-10," *i.e.* within the ordinary working range. Two of the observers were accustomed to the use of the R.A.F. system and were also trained scientific observers, while the third was a laboratory assistant, who had been an operator during the war but had had no experience in such measurements. Naturally, the results of the first two were at first more consistent than those of the third who has however improved rapidly with practice.

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The curves are given in Figs. 4 to 9.

Before discussing them in detail it is necessary to explain them slightly. The abscissæ (which are really milli-volts measured on galvanometer G) are taken as proportional to signal strength as mentioned above.

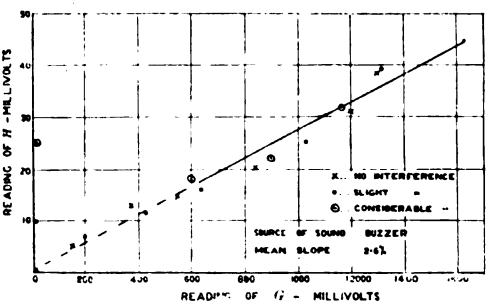

FIG. 4.

The same proportion holds for all the points on any one sheet but does not necessarily hold between the curves on different sheets owing to different adjustments for different buzzers.

The results all correspond to signals of a maximum intensity of about "R-10" and as will appear later owing to the particular shape of the curves obtained the absolute value is of secondary importance.

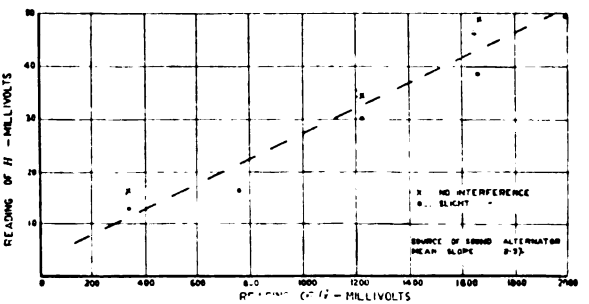

FIG. 5.

The ordinates are the milli-volts measured by galvanometer H, so that the ratio of ordinates to abscissæ gives in every case the percentage change in signal strength which is just audible at that particular signal strength. This will in future be referred to as the "critical change." It is owing to this ratio being approximately constant for each single experiment that the question of accurate absolute determination of signal strength is not so vital. Each sheet contains the tests by a single observer on the same buzzer under various conditions of interference. The two sources of sound were :—

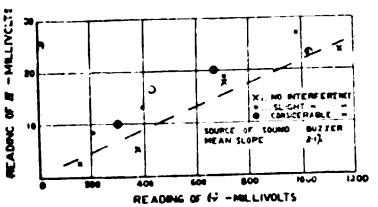

FIG. 6

A buzzer giving a high pitched musical note.

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An alternator giving a very pleasant mellow musical note nearly an octave below the buzzers.

The interference in each case consisted of a constantly vibrating buzzer of low frequency producing a whirring noise. "Slight interference" corresponds to a signal strength about "R-3," "considerable interference" to one of about "R-7." The difference in the quality of the sound was so great that no possible confusion could arise. In discussing these curves the personal factors will be considered first. Figs. 4 and 5 were obtained by the author, 6 and 7 by his assistant, 8 and 9 by a colleague. The mean curves on each sheet have been drawn as fairly as possible, but it will at once be admitted that in measurements of this type which contain other than purely mathematical factors the accuracy and consistency will not be very high. The vertical scale is also large compared with the horizontal.

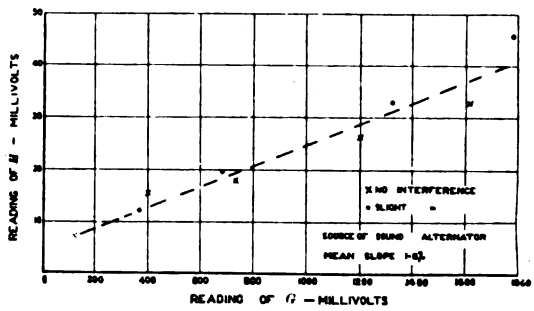

FIG. 7.

The first four are approximately straight lines, but the author's lines in each case give definitely steeper slope.

This is probably due to two causes; the author has found that his hearing is slightly less keen than that of the average operator, and also his experience has led to his always working for a very definite variation in audibility. In this experiment, as the difference between the signal strengths for the two key positions is increased, one passes from a stage of no audible difference, through a stage of barely perceptible difference to a stage of definite difference. The range of the second stage varies so much with such factors as fatigue that it is always safer to work to the third stage. The figures may be larger but they are far more consistent. As a matter of fact each point shown is the mean of several readings, and by working always to the third stage the individual results approach much closer to the mean. The curves of Figs. 8 and 9, however, show a distinct upward tendency. They were obtained by his colleague Mr. Hoyle who has had considerable W/T experience and who admits that he has a great physical dislike to loud signals and always works with the weakest signals possible; so that this upward curve is probably a directly physiological effect. If the signal strengths were much increased it is likely that everybody

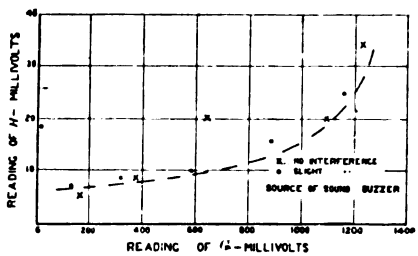

FIG. 8.

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would show a similar effect, but the point at which it occurs varies with individuals.

Further tests have since been carried out on people who had had no experience whatever with the reception of audible signals.

At first their results are very irregular, due probably to the strangeness of such a form of measurement, but though the variations of separate readings are large the mean of a considerable number is but little different to that of a trained observer. Sensitivity appears to be innate and it is consistency which improved by practice.

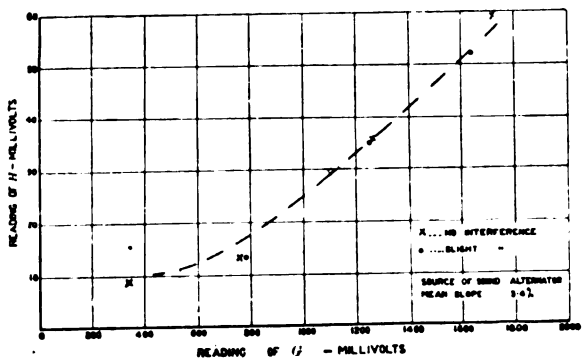

FIG. 9.

After allowing for all these factors the following very interesting results emerge :—

(1) Except at very weak signals (about " R-2 ") the critical change is a definite percentage of the signal strength. At very low signal strengths the critical change appears to become constant with no interference or to rise if interference is present, but especially in the former case these measurements are extremely difficult to obtain, and the time for which each signal must be listened to is much greater. On very loud signals the percentage appears to increase.

(2) This percentage varies with different observers and with different sources of sound from 2 per cent. to 4 per cent. Captain Robinson gives this as 8 per cent. derived from actual experience. It is very probable that in the air the 2 per cent. to 4 per cent. should be increased, but in the coil sets from which his results are drawn, it is likely that the " pick-ups " in the leads and amplifier were considerable. This of course produces an apparent increase in the percentage value as deduced from coil dimensions.

(3) Above a certain weak signal strength reasonable interference does not affect the sensitivity, and this strength is far below the strength of the interference signal, provided that the quality of the sounds is different. This is a striking and surprising result.

(4) Interference enormously increases the minimum audible signal strength as will be seen by the points on the axis. The strength of

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signal given by these points is excessively weak, the presence of the signal was just noticeable but no message could have been read.

(5) When interference is present the critical change at low signal strengths is actually less than the signal strength required to give the minimum audible sound.

It will be noticed that in this experiment the least audible difference is the factor which has been submitted to measurement, whereas in actually measuring directions it is equality of signals which is used. This procedure was adopted intentionally as it was thought that there would probably occur a certain range over which the signals appeared equal, and it would require a great number of " equality " measurements to determine the limits of this range. The " critical change " however marks the limit of this range and so gives definitely the limit of accuracy which can be obtained. That is to say that if the " critical change " is 2 per cent. and an apparent equality of balance is obtained it means that the two signals must actually differ by *less* than 2 per cent. Hence this method gives a definite but conservative measure of the true sensitivity.

These results, though theoretical, have a very direct bearing on the efficiency and working conditions of the R.A.F. system.

Considering first an existing coil of definite dimensions (1) shows that the sensitivity of the set is unaffected by the signal strength within fairly wide limits, since a definite displacement of the set from the zero position of the auxiliary coil produces a definite percentage change in the total E.M.F. in the circuit whether this E.M.F. be large or small. As a result of this provided the amplifier remains unsaturated its actual characteristic is not important. (2) Shows that for signals of fair strength the accuracy is not affected by constant interference noises such as valve noises or commutation hum from a neighbouring supply system. Directive interference is of course as serious as in all systems.

Returning now to the converse problem, that of design, these results will be of great assistance in the determination of the area-turns of the two coils. Since (1) shows that the exact signal strength is not of importance, it is well, when possible, to design the main coil so as to give a signal of fair strength on the weakest station on which measurements are required to be made. In many cases it is desirable to provide about 50 per cent. more turns which can be brought into action by a switch in order to enable measurements to be carried out if necessary under unfavourable circumstances, but these extra turns when not in use should be completely isolated from the coils to avoid vertical effect from the over-hanging turns.

Having fixed the main coil the area-turns on the auxiliary coil can now be determined by use of the percentage value obtained in (2).

In choosing the exact figure the designer will of course have to use his discretion.

This comprises the outline of the method of design for coils working on this system. The question of the exact size and shape of coil and of size of wire will not be dealt with here further; it is one which has been considerably discussed in America especially by Blatterman in the paper referred to above.

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As in all designs considerable latitude has to be left to the discretion and experience of the designer, what is required is not a series of figures to enable an inexperienced person to produce some sort of a result; but a discussion of the various vital points and their relative importance. One interesting fact may be noted here. The coil frame referred to in the paper was constructed before this system was organised. Working backwards however from the actual measured sensitivity of the set and the known value of the area-turns it gives a figure for the critical change of 3 per cent., which is well in agreement with the figures obtained from the theoretical considerations.

The foregoing description and discussion covers all that has been experimentally investigated up to the present.

On the one hand it is incomplete in many particulars; the problems of continuous waves and of short wave work will no doubt bring in many special difficulties of their own.

On the other hand some points may seem to have been dealt with in unnecessary detail. The aim underlying the whole investigation has been to reduce the problem as far as possible to one of systematic design. Sets may, and have, no doubt been built which have given satisfactory results but in which many of the smaller points have been disregarded. It may be taken that for a sensitivity of 1° or over very few precautions either in design or operation need be taken. From 1° to ½° more care is required, but below ½° the possible errors multiply very rapidly. With skill and practice in operation many of these can be reduced or eliminated; but a system can hardly be regarded as satisfactory unless the calls on the operator's skill have been reduced to the minimum. This can only be done by close investigation, and by the incorporation of the protective measures in the design to the greatest possible extent, so as to open the power of accurate measurement even to those whose skill and experience in the particular type of work involved are less.

Measurement of the Signals Received in Washington from the Lafayette Station.*

By Dr. L. W. AUSTIN

(U.S. Naval Research Laboratory).

The sending tests of the Lafayette Station during August and early September, 1920, have given an opportunity for a further trial of the radio transmission formula at a wavelength much greater than has been hitherto investigated.

The method of reception was essentially that described in the measurements on Nauen † except that the measurement telephones are now placed

* Received January 26th, 1921.

† Quantitative Measurements at Washington on the Signals from the German Radio Stations at Nauen and Eilvese. *Journal of the Franklin Institute*, 182, pp. 605–611, November, 1916.

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in series with the plate battery of the oscillating vacuum tube. The shunting resistance is of a type devised by G. W. Pickard which throws impedance into the line as the telephone is shunted, so as to keep the total impedance nearly constant. The receiving set is calibrated in essentially the same manner as has been already described * except that now a shunted galvanometer and detector † are placed directly in the artificial antenna circuit for the measurement of the calibrating antenna current instead of being coupled as formerly. As an additional check on the calibration, audibilities were taken on signals from Arlington using a few milliamperes in the antenna. At this distance, a little more than a wavelength away from the laboratory, no errors due to direct action on the secondary of the receiving set, or of absorption, can enter into the calculation of the field at the receiving station. The two methods of calibration were in complete agreement.

Full descriptions of the Lafayette Station have appeared in a number of the scientific journals.‡ The effective height of the antenna has not been announced but it may be safely assumed to be approximately seven-tenths of the height of the masts, or one hundred and seventy metres.

The observations on the audibility of the received signals are shown in Table I., while the necessary data for calculation and the calculated values of received current and audibility are given below. For comparison, the average audibilities of Nauen and Lyons, taken between 9 and 10 a.m. on the same days, are included. It is seen that the agreement between observed and calculated values is satisfactory, as of course the formula only claims to represent average results of observations extending over long periods of time.

TABLE I.

Lafayette received in Washington.

Date.	Observed Audibility. 8 a.m	12 noon.
Aug. 25	3,000	1,500
,, 26	3,000	2,000
,, 27	2,000	1,500
,, 28	3,000	1,500
,, 29	1,500	1,000
,, 30	2,000	800
,, 31	800	800
Sept. 1	1,000	600
,, 2	2,000	1,500
,, 3	—	3,000
Average audibility . .		1,700

* *Proceedings of the Institute of Radio Engineers*, 5, p. 239, 1917.
† *Proceedings of the Institute of Radio Engineers*, 7, p. 257, 1919.
‡ See pp. 85—93 of the February issue.

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Data for Calculation.

$$\text{Received current } I_r = 377 \frac{I_s h_1 h_2}{\lambda d R} \epsilon^{-0.0015d/\sqrt{\lambda}} \text{ amp.}$$

Data for Lafayette:—

Sending current $I_s = 475$ amps.
Receiving height $h_2 = 0.0164$ km.
Distance $d = 6{,}160$ km.
$\epsilon^{-0.0015d/\sqrt{\lambda}} = 0.148$.
Power for unit audibility $= 1.5 \times 10^{-15}$
Sending height $h_1 = 0.170$ km.
Wavelength $\lambda = 23.4$ km.
Receiving resistance $R = 135$ ohms.
E_0 = Field intensity, volts per metre.
Audibility proportional to $\sqrt{\text{Power}}$.

Data for Nauen:—

$I_s = 320$ amps.*
$R = 83$ ohms.
$h_1 = 0.150$ km.†
$d = 6{,}650$ km.
$\lambda = 12.5$ km.
$\epsilon^{-0.0015d/\sqrt{\lambda}} = 0.059$.

Data for Lyons:—

$I_s = 250$ amps.*
$R = 90$ ohms.
$h_1 = 0.120$ km.†
$d = 6{,}460$ km.
$\lambda = 15.0$ k.
$\epsilon^{-0.0015d/\sqrt{\lambda}} = 0.081$.

TABLE II.

	Lafayette		Nauen.		Lyons.	
	Calculated.	Observed.	Calculated.	Observed.	Calculated.	Observed.
Audibility ...	1,130	1,700	600	467	420	167
I_r amps ...	$3.79.10^{-6}$	$5.7.10^{-6}$	$2.54.10^{-6}$	$1.98.10^{-6}$	$1.72.10^{-6}$	$6.85.10^{-7}$
E_0 volts/metre	$3.11.10^{-5}$	$4.67.10^{-5}$	$1.29.10^{-5}$	$1.01.10^{-5}$	$9.45.10^{-6}$	$3.75.10^{-6}$

A Use for the Valve in Wireless Measurements.‡

By H. J. ROUND.

A method of signal measurement has been in use in the Marconi Company during the last ten years which has recently been extended and developed for other purposes than that of pure signal measurement.

The original method is shown in Fig. 1. J is the oscillatory circuit, in which the strength of signals is to be measured. A Fleming valve F, the filament current of which is supplied by the battery B_1, is placed in series with the potentiometer device $P B_2$ and the telephone attachment T C across the condenser of the circuit J.

If extremely weak signals are now induced into J such that they are just

* Reported.
† Estimated.
‡ Received in final form, January 29th, 1921.

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audible at one point only on the potentiometer P B_2, this position of the potentiometer can be called the zero point. The voltmeter reading is taken when this zero point is reached and is found to be, say, V_0. The normal signals to be measured are then produced and the slider of the potentiometer moved towards the negative end of the battery B_2 until signals again just vanish.

A second reading V_1 of the voltmeter is now taken and the value $V_1 - V_0$

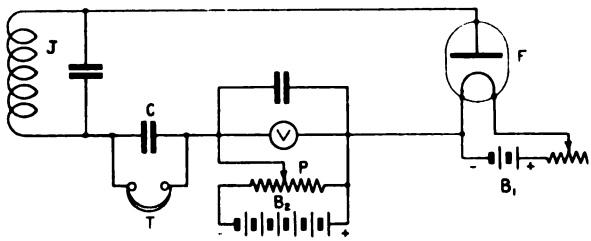

FIG. 1.

gives the maximum voltage of the signal; $V_1 - V_0$ being known as the "slide-back" voltage.

Fig. 2 represents a rectifying characteristic of a Fleming valve. A represents a weak signal for determining the zero and B represents a stronger signal, the slide-back voltage having been adjusted so that there is only a trace of rectification, namely when the wave train is at its maximum amplitude. The voltage $V_1 - V_0$ is indicated by the distance x and is obviously approximately equal to the maximum voltage of the signal.

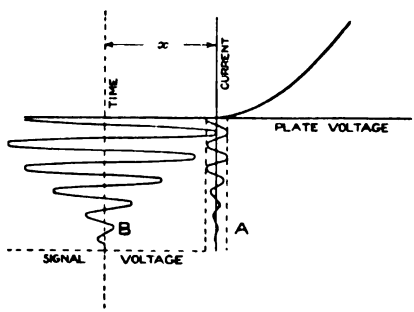

FIG. 2.

A series of graphs taken in 1911, between oscillatory current in J and the slide-back voltage gave straight lines through the origin up to values of voltage of 50, beyond which they were not taken. These original measurements, when the device was first adopted, were taken on spark stations and exactly what one was measuring, if spark frequency and damping varied, was difficult to say, but for the measurement of attenuation with increase of distance between the receiver and a source of signals of uniform strength—such as a high power Spark Station working on programmes—the method was simple in operation and gave consistent results.

With continuous waves the case is altered and the peak voltage corresponding to $V_1 - V_0$ may be taken as a measure of the R.M.S. voltage of the received signals. There is an element of doubt owing to the introduction of the small damping of the Fleming valve when used at a point at which

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telephone signals were just audible and this difficulty has been surmounted by the use of the three-electrode valve with a modified circuit.

This modification is particularly adaptable for measurements in circuits of very low damping, and the usual arrangement is shown in Fig. 3. The Fleming valve is replaced by the three-electrode valve D, the signals in the circuit J being applied to the grid in series with which is a considerable negative E.M.F. so that during the operation no grid current whatever can flow. The presence of any grid current is indicated by the galvanometer G_1. A second galvanometer G_2 is placed in the anode circuit in series with which is a battery B_3 which must be of sufficient voltage to enable plenty of indication of current in G_2 when no grid current is flowing in G_1.

On sliding the potentiometer P towards the negative end a point can be found such that the galvanometer G_2 indicates a condition of zero anode current. The potential difference between the potentiometer slider, when in this position, and any other arbitrary point of fixed potential, may be taken as a measure of the voltage V_0.

Now on applying signals to J in the form of spark or continuous wave, a further negative slide-back will be required in order to reduce the anode current to zero again and the new voltage, V_1, of the potentiometer slider, measured as before, will now be greater than V_0 by the amount of the peak voltage of the alternating E.M.F. induced in J by the signal.

A fairly close mesh valve with the mesh well enclosing the filament tends to give definite zeros, but a Marconi V-24 or a French valve, if chosen so that the filament is not sticking out at the ends of the grid too much, is quite good. With these two latter valves, the two galvanometers can be Weston Model 375 or Paul Unipivot 5-ohm type. One galvanometer only need be used with a switch which enables it to be inserted occasionally in the grid circuit to make sure that no current is flowing.

The potentiometer battery can be about 25 volts and B_3 up to 20 volts.

Since the method only involves readings taken when no anode current is flowing, the possibility of reaction effects being introduced by the valve may be neglected.

With unearthed circuits of small capacity, care has to be taken that the

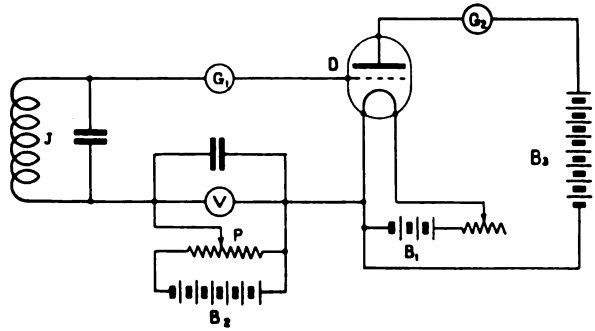

FIG. 3.

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battery system is not influencing the readings, and in circuits with a considerable amount of distributed capacity, the effect of this must be taken into account.

Referring to Fig. 3, if J is an oscillatory circuit such as an aerial—the valve being tapped off some part of the inductance of the circuit and not necessarily all—its resistance can be determined immediately if a constant source of oscillations is obtainable. Such a source may be obtained from one or two French type valves with a 200 volt supply from the mains or from large dry cells the whole arranged to give oscillations of the desired frequency.

To measure the resistance of J it is necessary to induce into J from the oscillator, with J tuned up, and measure the slide-back voltage, subtracting the zero voltage reading which was obtained with the oscillator not working. Then insert two or three values of non-inductive resistance r into J and measure the slide-back volts again. As net slide-back is proportional to current, and as the induced E.M.F. is constant, a simple calculation gives the value of R, the resistance of J. The values given when using different resistances should correspond.

When this substitution method is being used with a hot wire instrument, some difficulty is always experienced in tuning up to get maximum readings, but with this null method, it is easily seen that it is merely necessary to go through the point of tune watching for any slight kick of the galvanometer G_2. When measuring a swaying aerial of very low damping, this point is of considerable importance.

Instead of reading the value of $V_1 - V_0$ with a galvanometer G_2, a telephone with a make and break on the anode circuit can be used, or a telephone and a very weak separate heterodyne. The latter has turned out to be a very useful modification when measuring the resistances of large aerials where the current values induced by stations such as Eiffel Tower are sufficient to give big slide-back voltages. The use of the heterodyne makes it possible to concentrate only on one's own induced current from the oscillator, and also to watch whether the oscillator is too tightly coupled to J in which latter case a perceptible change of heterodyne note occurs as J is passing through the resonance value of the oscillator, and this should be avoided. The heterodyne method is also preferable in measurement of signal strength from other stations but the heterodyne should be so loosely coupled as to have a negligible value of $V_1 - V_0$ and in this case the normal large ratio of heterodyne current to signal is reversed, a condition unsuitable for weak signal measurement.

Coupling should be made from the oscillator, by means of a few turns in the oscillatory circuit next to the batteries (*i.e.*, the low potential end) brought near to the circuit being measured, the remainder of the oscillator circuit being a few feet away (see Fig. 4).

The apparatus used is simple and with the possible exception of the voltmeter, is all ordinary receiving circuit equipment. It may also be mentioned that only about a fifth the power is necessary that would be required to operate a thermo-ammeter.

Without the introduction of amplifiers, this slide-back method is not of

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much use for the measurement of modern signals as the latter are of such small voltages unless amplified and then the measurement of the law of the amplifier introduces considerable possibilities of errors.

The same slide-back method can be used for determining the voltage across various pieces of apparatus without disturbing the apparatus unless the capacity of the latter is of too small an order. For instance, the voltage magnification steps can be measured on a high frequency or low frequency

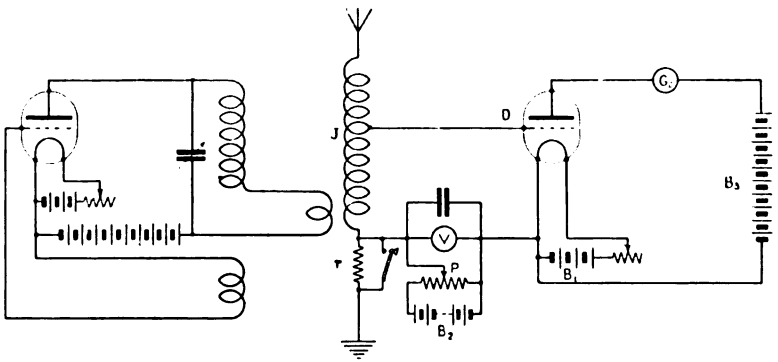

FIG. 4.

amplifier or telephone voltages can be read across resistances or inductances on telephone lines—or of course, actual aerial currents in a receiver can be measured.

The above method suggested that the valve can be used for other measurement purposes, for instance if high voltages have to be read, a null method using a valve with a high "μ" value can be used (where $\mu = -\frac{\partial e_p}{\partial e_g}$ with a constant value of plate current). The valve can be operated with its filament so dull that the saturation current is just sufficient to give a distinct indication on G_2 (see Fig. 3). The amount of slide-back on P multiplied by the value of μ is the voltage V.

The various ways of obtaining the value of μ have been so thoroughly described that it is not necessary to go into them here.

The Manufacture of Radio Apparatus in France.

We have received from the Société Française Radio-Électrique some interesting photographs and particulars of the works maintained by that company in conjunction with the Compagnie Générale de Télégraphie sans Fil and the Compagnie d'Exploitation Radio-Électrique. These three companies are now associated with one another to specialise both in the construction and operation of radio installations.

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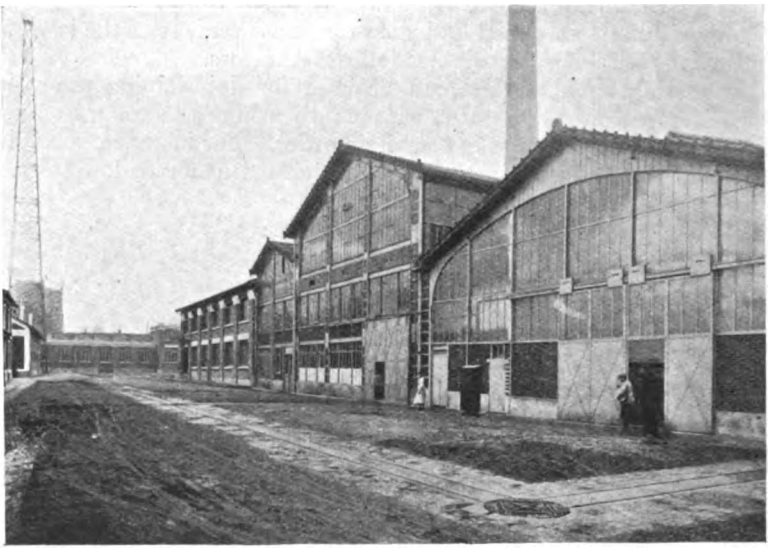

FIG. 1.—Front View of the Machine Shop, Offices, etc., of the Levallois Works.

The works at Levallois of which we published an illustration in the March issue of the RADIO REVIEW (p. 132) cover an area of 12,000 square metres and are devoted to the manufacture of all kinds of radio apparatus with the exception of the largest machines. Experimental research is also conducted at these works. Another view of the front of the offices and workshops is shown in Fig. 1 in which illustration one of the antenna supporting towers may also be seen. A permanent radio station is fitted

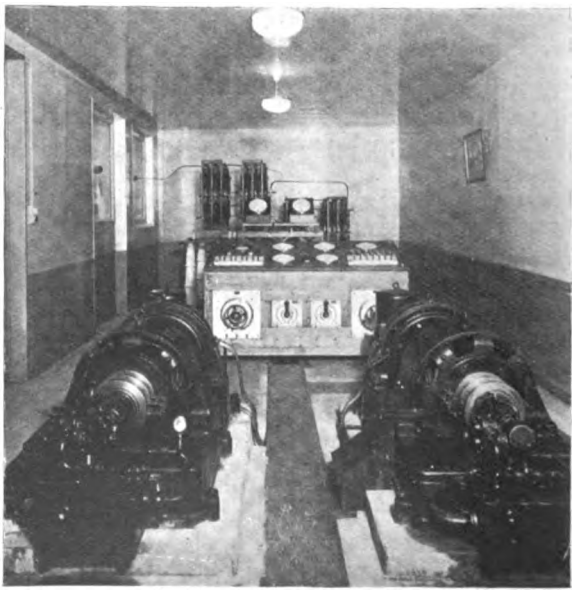

FIG. 2.—50-kW Transmitting Installation at the Levallois Works.

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up in these works capable of an output of about 50 kW in the antenna using either of two sources of energy—H.F. alternators or valves. Fig. 2 illustrates this installation and shows the two H.F. alternators each of 25 kW output. These may be operated in parallel with high speed transmission.

FIG. 3.—Drawing Office—Levallois Works.

The works themselves consist of three bays comprising the machine shops, despatching room, test rooms, experimental reception rooms, laboratories, offices, drawing offices, stores, etc. Some of these departments are illustrated in Figs. 3, 4, 5 and 6.

FIG. 4.—Machine Shop—Levallois Works.

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FIG. 5.—Finished Parts Stores—Levallois Works.

The works at Lyon-Venissieux cover an area of 27,000 square metres and are devoted entirely to the manufacture of antenna towers. An exterior

FIG. 6.— Miscellaneous Stores—Levallois Works.

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FIG. 7.—General View of the Venissieux Works, showing Aerial of Experimental Stations.

view of these works is shown in Fig. 7, together with the supporting tower for the umbrella aerial which is used for experimental work. This tower is 100 metres high and the antenna can be excited by a 25 kW H.F. alter-

FIG. 8.—Venissieux Works, Closer View.

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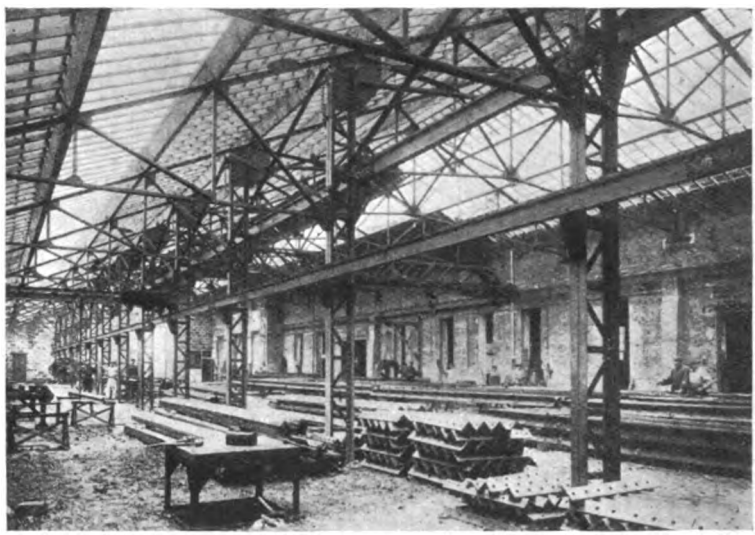

FIG. 9.—Mast Assembly Shop—Venissieux Works.

nator or by a valve transmitter. Fig. 8 is a closer view of the buildings and Fig. 9 shows the assembling shop in these works.

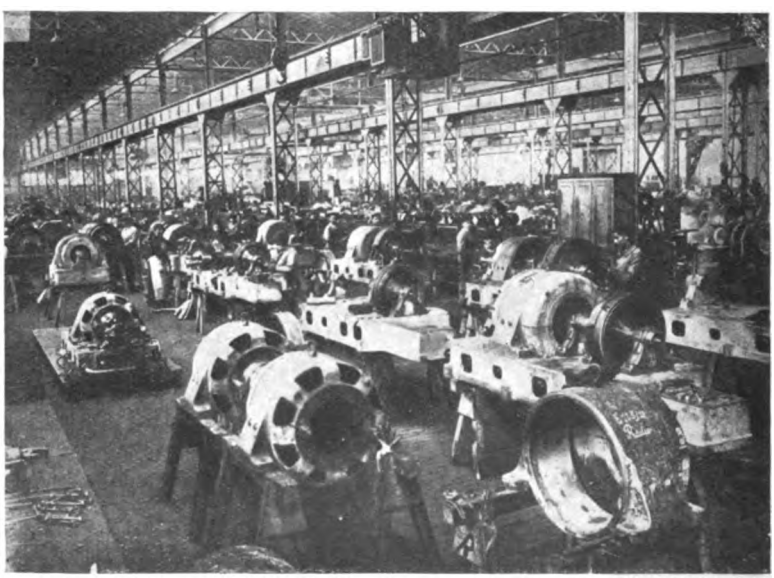

FIG. 10.—Assembly Shop for Medium Power H.F. Alternators—Belfort Works.

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The H.F. alternators and large electrical machinery are manufactured in the Belfort Works of the Société Alsacienne de Constructions Mécaniques which firm is associated with the Société Française Radio-Électrique. A group of H.F. alternators under construction in these works was illustrated on p. 129 of the March issue of the RADIO REVIEW. The assembly shop for medium power H.F. alternators may be seen in Fig. 10. These works have for many years been engaged in the construction of both electrical and mechanical machinery of all sizes such as turbines, turbo-dynamos, locomotives, etc., and certain sections of the works are now devoted entirely to the construction of the machines for the Société Française Radio-Électrique.

Triode Oscillation Generators with Coupled Oscillatory Circuits.*

By F. HARMS.

A well-known phenomenon when tuning an antenna to an oscillatory circuit maintained by a triode is the sudden jump which occurs in both the current and the frequency as the inductance or capacity of the aerial circuit passes through a certain value. On passing back to the previous condition the jump occurs for a different value of the adjustable inductance or capacity. In Fig. 1 the antenna current is plotted against the capacity of the secondary or aerial circuit in a certain case. On increasing C_2 the current follows the curve 123456, whereas on decreasing C_2 it follows 653721.

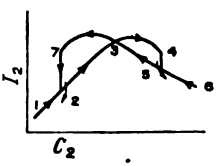

FIG. 1.

I. Production of Oscillations by Means of a Triode.

Before considering the case of the two coupled oscillatory circuits, we shall consider the simple triode circuit shown in Fig. 2. We have the following equations :—

$$i_a = Sv_g + \frac{1}{R_i} v_a + c \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where $$S = \left(\frac{\partial i_a}{\partial v_g}\right)_{v_a = \text{constant}}$$

and $$R_i = \left(\frac{\partial v_a}{\partial i_a}\right)_{v_g = \text{constant}}$$

in other words S is the slope of the characteristic, and R_i is the internal resistance of the triode.

* Abstracted from the *Jahrbuch Zeitschrift für drahtlose Telegraphie* -see Abstract No. 1927 in this issue for references.

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$$R_1 i_L + L_1 \frac{di_L}{dt} = \frac{1}{C_1}\int i_C dt = v \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where v is the voltage across the condenser

$$i_a = i_L + i_C \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$v_a = E_a - \left(R_1 i_L + L_1 \frac{di_L}{dt}\right) = E_a - v \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where v_a is the anode voltage.

$$v_g = E_g - M\frac{di_L}{dt} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where v_g is the grid voltage, the grid current being assumed so small that the effect of L_g is negligible.

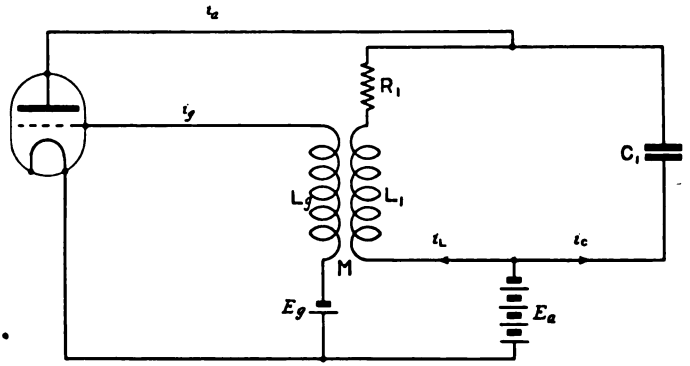

FIG. 2.

When the circuit is not oscillating we have the steady condition represented by the formula

$$I_a = SE_g + \frac{1}{R_i}(E_a - R_1 I_a) + c \quad . \quad . \quad . \quad . \quad . \quad . \quad (1a)$$

By elimination from these six equations we get

$$\alpha\frac{d^2v}{dt^2} + \beta\frac{dv}{dt} + \gamma v = \epsilon \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where $\alpha = C_1 L_1 \qquad \beta = C_1 R_1 + SM + \frac{L_1}{R_i}$ . . . . . (7)

$$\gamma = 1 + \frac{R_1}{R_i} \qquad \epsilon = I_a R_1 \left(1 + \frac{R_1}{R_i}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

On comparing this equation with that for the ordinary oscillatory circuit it will be seen that to get zero damping, that is, a sustained oscillation, β must vanish, and therefore

$$-SM = C_1 R_1 + \frac{L_1}{R_i} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

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For the oscillation to build up, SM must have a larger value than this, that is to say, omitting the negative sign

$$SM > C_1R_1 + \frac{L_1}{R_i} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9a)$$

From (7) and (8), the frequency of the sustained oscillations is seen to be

$$f = \frac{1}{2\pi}\sqrt{\frac{1 + R_1/R_i}{C_1L_1}}$$

in which R_1/R_i is practically negligible.

II. Maximum Amplitude of the Oscillation.

As the oscillation builds up the anode current passes beyond the knee of the characteristic and the slope of the curve is variable; as an approximation one may assume that the curve is replaced by a straight line through the end points as in Fig. 3. The equivalent steepness will then be *

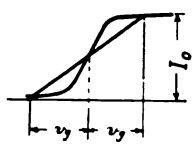

FIG. 3.

$$S = \frac{I_0}{2v_g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

and

$$v_g = \frac{I_0}{2} \cdot \frac{1}{S} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Substituting for S from equation (9) we have

$$v_g = \frac{I_0}{2} \frac{M}{C_1R_1 + L_1/R_i} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11a)$$

From equation (5) we have for the amplitude of the steady oscillation of grid potential

$$\hat{v}_g = \omega M \hat{\imath}_L \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

[*Note.*—The sign $\wedge$ represents maximum or crest values.]
From equations (11a) and (12)

$$\hat{\imath}_L = \frac{I_0}{2\omega} \cdot \frac{1}{C_1R_1 + L_1/R_i} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

It must be remembered that the denominator must not exceed a certain value (equation (9)) or oscillations become impossible. In consequence of this, on varying the constants of the circuit, the oscillations do not start up with gradually increasing amplitude, but suddenly with a considerable amplitude.

It follows from (13) that the amplitude is a maximum when

$$\frac{L_1}{C_1R_1} = R_i \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

* Rukop has pointed out (*Jahrbuch*, March, 1921, p. 218) that equation (10) is incorrect owing to neglect of the variable anode voltage. This modifies several of the following equations and conclusions.

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III. Forced Oscillations in Two Coupled Circuits.

If a periodic E.M.F. $e.\epsilon^{j\omega t}$ act on the first circuit (Fig. 4) the differential equations for the currents in the two circuits are

$$\left.\begin{aligned} L_1\frac{d^2i_1}{dt^2} + R_1\frac{di_1}{dt} + \frac{1}{C_1}i_1 + M\frac{d^2i_2}{dt^2} &= j\omega e\,.\,\epsilon^{j\omega t} \\ L_2\frac{d^2i_2}{dt^2} + R_2\frac{di_2}{dt} + \frac{1}{C_2}i_2 + M\frac{d^2i_1}{dt^2} &= 0 \end{aligned}\right\} \quad . \quad . \quad (15)$$

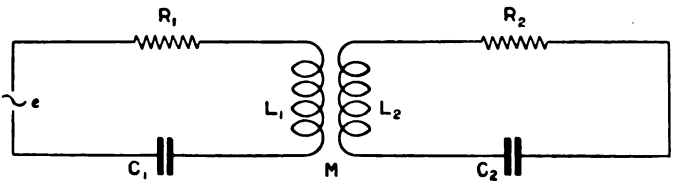

FIG. 4.

If a stationary condition is possible it will be given by

$$i_1 = A_1\epsilon^{j\omega t} \text{ and } i_2 = A_2\epsilon^{j\omega t} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

Substituting these in equations (15) we obtain

$$\left.\begin{aligned} -L_1A_1\omega^2 + R_1A_1j\omega + \frac{1}{C_1}A_1 - MA_2\omega^2 &= ej\omega \\ -L_2A_2\omega^2 + R_2A_2j\omega + \frac{1}{C_2}A_2 - MA_1\omega^2 &= 0 \end{aligned}\right\} \quad . \quad . \quad (17)$$

Introducing now an equivalent resistance R and an equivalent inductance L, such that

$$R = R_1 + \omega^2M^2\frac{R_2}{Z_2^2} \text{ and } L = L_1 - \omega^2M^2\frac{L_2 - \frac{1}{\omega^2C_2}}{Z_2^2} \quad . \quad . \quad . \quad (18)$$

where $$Z_2^2 = R_2^2 + \left(\omega L_2 - \frac{1}{\omega C_2}\right)^2$$

the equation for the first circuit is seen to be the same as if the second circuit were absent except that it has these equivalent values of L and R which, however, depend on the frequency. It is thus found that

$$\left.\begin{aligned} \hat{i}_1 &= \frac{\hat{e}}{\sqrt{R^2 + \omega^2\left(L - \frac{1}{\omega^2C_1}\right)^2}} \\ \hat{i}_2 &= \hat{i}_1\frac{\omega M}{Z_2} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (19)$$

We have seen that the frequency of a transmitting valve set is approximately the undamped frequency of the circuit. Putting $R_1 = R_2 = 0$ and $e = 0$ in (15) we have the well-known equation

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$$\omega^4(1-k^2)-\omega^2(\omega_{10}^2+\omega_{20}^2)+\omega_{10}^2\omega_{20}^2=0 \quad . \quad . \quad . \quad . \quad (20)$$

the solution of which gives the two possible frequencies,

$$\omega^2=\frac{\omega_{10}^2+\omega_{20}^2}{2(1-k^2)}\pm\sqrt{-\frac{\omega_{10}^2\omega_{20}^2}{1-k^2}+\left(\frac{\omega_{10}^2+\omega_{20}^2}{2(1-k^2)}\right)^2} \quad . \quad . \quad (21)$$

The values of the two coupled frequencies calculated by this equation for a particular example are plotted in Fig. 5 for various values of C_2. They lie outside the natural frequencies of the two circuits, and except for very loose coupling, differ considerably from them.

IV. The Conditions for the Oscillation of Coupled Valve Circuits and the Current in the Secondary Circuit.

Except that the equivalent values L and R have to be substituted for L_1 and R_1, the equations already established and especially (9) and (13) are unaltered. Since, however, L and R depend on the frequency, different values will be obtained for them and for the conditions for the setting up of oscillations and for the amplitude of the current, depending on which of the two coupled frequencies ω' and ω'' be employed. We thus obtain the following equations which enable us to explain all the discontinuous phenomena of valve oscillators with magnetic coupling.

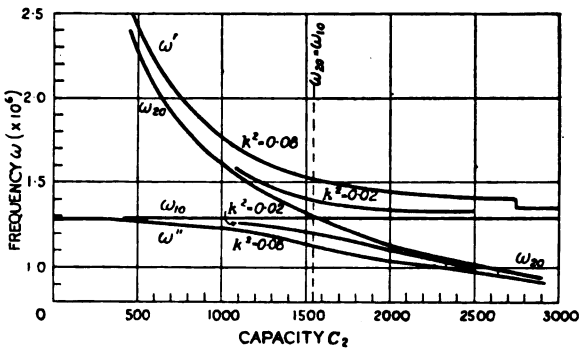

FIG. 5.

For the oscillation of frequency $\omega'/2\pi$

$$SM > \frac{L'}{R_i}+C_1R'$$

$$i_L=\frac{I_0}{2\omega'}\cdot\frac{1}{\frac{L'}{R_i}+C_1R'}$$

For the oscillation of frequency $\omega''/2\pi$ . . . . . (22)

$$SM > \frac{L''}{R_i}+C_1R''$$

$$i_L=\frac{I_0}{2\omega''}\cdot\frac{1}{\frac{L''}{R_i}+C_1R''}$$

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From these equations and (19) we have

$$\left.\begin{aligned} i_2' &= \frac{I_0}{2} \cdot \frac{M}{\frac{L'}{R_i} + C_1 R'} \cdot \frac{1}{Z_2} \\ &= \frac{I_0}{2} \cdot \sqrt{L_1 L_2} \cdot \frac{k}{Z_2\left(\frac{L'}{R_i} + C_1 R'\right)} \end{aligned}\right\} \quad \ldots\ldots\ldots (23)$$

and

$$i_2'' = \frac{I_0}{2} \sqrt{L_1 L_2} \frac{k}{Z_2\left(\frac{L''}{R_i} + C_1 R''\right)}$$

In these equations R' and L' are the values of R and L for the coupled frequency ω', and R'' and L'' those for the coupled frequency ω''.

V. A Numerical Example.

We assume a triode with $S = 10^{-4}$, $R_i = 10^5$ and therefore a voltage ratio of 10; we take the mutual inductance M between the anode and grid circuits to be $2 \cdot 10^5$ cm. We calculate for the range $C_2 = 1{,}000$ to $2{,}500$ cm the values of ω'^2 and ω''^2 from equation (21) and the corresponding values of Z_2, L and R. We then calculate the values of A, where

$$A = \frac{L}{R_i} + C_1 R \quad \ldots\ldots\ldots (24)$$

and of

$$\frac{k}{ZA} \quad \ldots\ldots\ldots (25)$$

which is proportional to the amplitude of the secondary current.

The so calculated values are given in Tables I. and II. on the assumption that

$L_1 = 4 \cdot 10^5$ cm. $\quad C_1 = 1{,}360$ cm. $\quad R_1 = 1$ ohm.

$L_2 = 3{\cdot}5 \cdot 10^5$ cm. $\quad R_2 = 7{\cdot}3$ ohm.

In the first table $k^2 = 0{\cdot}08$ and in the second $k^2 = 0{\cdot}02$, the change being effected by moving the coils relatively to one another without varying their self-inductances.

The curves of A and i_2 are plotted in Figs. 6 and 7 in which the dot-dash straight line shows the value of SM ($S = 10^{-4}$ ohm^{-1}; $M = 2.10^{-4}$ henry $\therefore SM = 2.10^{-8}$). Oscillations are possible whenever the A curve lies below this line. For $k^2 = 0{\cdot}08$ the oscillation ω' with the greater frequency and therefore shorter wavelength, is possible for values of C_2 above 1,400 cm, those with the longer wavelength for values of C_2 below 1,630 cm. Between 1,400 and 1,630 cm both oscillations are possible. On switching on in this range both oscillations are present at first, but that with the smaller value of A increases more rapidly in amplitude and reaches sooner that value of grid potential for which the anode current is nearly independent of the grid

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TABLE I.—$k^2 = 0{\cdot}08$.

C_2 cms	$\omega_{20}^2 \times 10^{12}$	$\omega'^2 \times 10^{12}$	$\omega''^2 \times 10^{12}$	$Z_2'^2$ (ohm)^2	$Z_2''^2$ (ohm)^2	$L' \times 10^5$	$L'' \times 10^5$	R' ohms	R'' ohms	$A' \times 10^{-8}$	$A'' \times 10^{-8}$	i_2' / $\times 10^{-5} \times \frac{I_0}{2} \times \sqrt{L_1 L_2}$	i_2'' / $\times 10^{-5} \times \frac{I_0}{2} \times \sqrt{L_1 L_2}$
500	5·14	5·8	1·60	96	980	1·14	4·14	41	2·0	6·1	0·57	4·86	5·1
1,100	2·34	2·90	1·45	114	254	2·35	4·52	19	2·8	3·07	0·87	7·8	12·4
1,300	1·98	2·56	1·39	132	178	2·64	4·75	13	4·7	2·21	1·19	9·4	12·9
1,500	1·71	2·37	1·29	150	133	2·85	5·00	9·6	7·4	1·74	1·62	10·5	12·7
1,700	1·51	2·20	1·20	168	100	3·00	5·24	7·5	11·4	1·44	2·24	11·3	12·2
1,900	1·35	2·14	1·13	186	76	3·13	5·56	6·0	17·0	1·22	3·13	12·0	11·5
2,100	1·22	2·08	1·04	204	58	3·22	5·90	5·0	24·5	1·08	4·29	12·4	11·0
2,300	1·12	2·04	0·99	222	45	3·30	6·36	4·3	37·5	0·98	6·34	12·5	9·6
2,500	1·03	1·99	0·94	240	37	3·34	7·10	3·8	65	0·91	10·5	12·5	7·0
3,000	0·86	1·96	0·79	275	28	3·57	8·4	3·1	201	0·82	31·2	12·1	3·1

TABLE II.—$k^2 = 0{\cdot}02$.

C_2 cms	$\omega_{20}^2 \times 10^{12}$	$\omega'^2 \times 10^{12}$	$\omega''^2 \times 10^{12}$	$Z_2'^2$ (ohm)^2	$Z_2''^2$ (ohm)^2	$L' \times 10^5$	$L'' \times 10^5$	R' ohms	R'' ohms	$A' \times 10^{-8}$	$A'' \times 10^{-8}$	i_2' / $\times 10^{5} \times \frac{I_0}{2} \times \sqrt{L_1 L_2}$	i_2'' / $\times 10^{5} \times \frac{I_0}{2} \times \sqrt{L_1 L_2}$
1,100	2·34	2·49	1·59	34	236	2·74	4·14	45	1·6	7·07	0·65	5·85	9·24
1,300	1·98	2·17	1·55	46	121	3·09	4·28	22	3·2	3·66	0·91	8·45	12·9
1,500	1·71	1·97	1·48	64	67	3·39	4·52	11	7·8	1·96	1·63	11·3	13·0
1,700	1·51	1·86	1·38	90	39	3·57	4·83	5·7	19	1·22	3·37	12·9	10·6
1,900	1·35	1·80	1·27	118	26	3·70	5·17	3·7	40	0·92	6·51	13·0	8·35
2,100	1·22	1·78	1·16	147	21	3·75	5·50	2·7	56	0·79	8·95	12·3	7·6
2,300	1·12	1·76	1·08	169	15	3·79	5·66	2·3	95	0·72	14·9	11·6	6·2
2,500	1·03	1·74	1·00	189	13	3·81	5·80	2·0	126	0·69	19·5	10·6	5·7

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potential and therefore of the small fluctuations of grid potential due to the weaker oscillation. The anode current therefore fails to reinforce the weaker oscillations in the grid circuit, and this oscillation dies out leaving only the other one. $C = 1{,}530$ cm is the critical point at which it appears uncertain which oscillation would be established.

If, however, the oscillation is first set up and then C_2 gradually varied, this oscillation will persist until it becomes impossible, the wavelength and current will then suddenly jump to the values corresponding to the other oscillation. In Fig. 6 for example, with large values of C_2 the first oscillation (ω') is obtained; as C_2 is diminished the aerial current increases, passes through a maximum which has nothing to do with resonance, then follows the curve 6, 5, 4, 7, when it suddenly jumps up to point 2, increases slightly and then decreases through 1. If one now increases C_2, the current follows the curve 1, 2, 3, then suddenly falls to 4 and increases through 4, 5, and 6 and so on. If the crossing point 5 lies within the region defined by the points 2, 3, 4, 7, the sudden changes of current are both in the same direction.

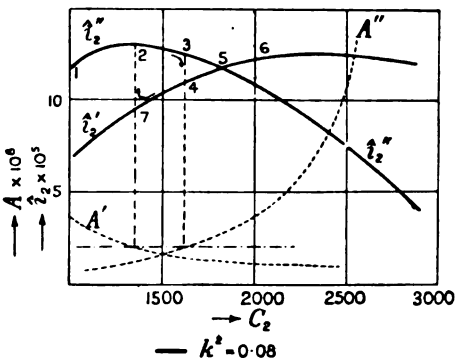

FIG. 6.

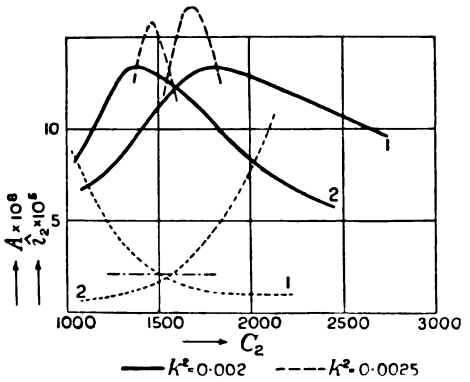

FIG. 7.

The essentially important magnitude in the phenomenon under discussion is A which is plotted in Fig. 8 for various values of the coupling. In the limiting case of infinitely loose coupling, the A curves become two horizontal lines which turn sharply vertical at $\omega_{20} = \omega_{10}$; in this case the two current curves coincide and there is no discontinuity. As soon as the coupling is tight enough to distinguish the two coupled frequencies, a jump in wavelength and current always occurs in the neighbourhood of $\omega_{20} = \omega_{10}$.

The effect of the ratio of L_1 to C_1 in the primary circuit on the nature of the phenomenon is shown in Fig. 9. The natural frequency of the circuits is the same in each case, but in the first case L_1 is small and in the second large. In the first case the antenna current jumps from a small to a large value, whereas in the second case the jump is in the reverse direction. The jump in the frequency is, however, always up when increasing C_2 and down when

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decreasing it. The ratio of L_1 to C_1 can be chosen such that the two current curves almost coincide with the result that the jump in the current is almost imperceptible; the jump in the frequency still occurs, however, and the aerial may therefore show the same current with the same value of C_2 on two occasions but be oscillating at a different wavelength.

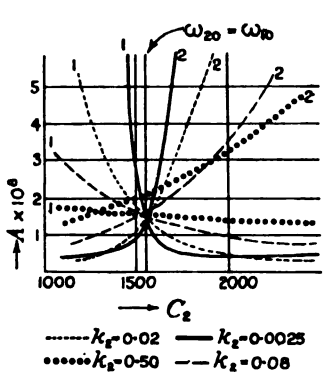

FIG. 8.

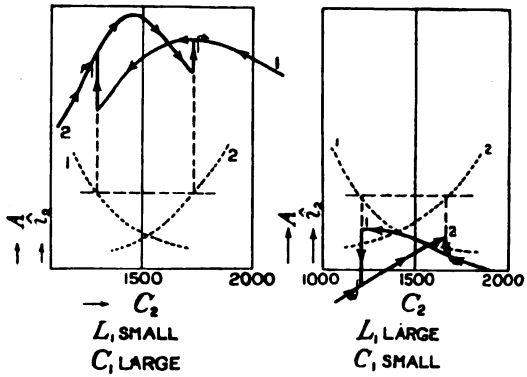

FIG. 9.

Equation (24) shows that a similar effect to that of varying the ratio L_1/C_1 may be obtained by varying R_i say by altering the filament current. The first case in Fig. 9 corresponds to a low temperature of filament and a consequently large value of R_i. All these results have been confirmed by experiments made by Seitz.*

The Current in the Primary Circuit.

From equation (22) we have

$$\hat{\imath}_L = \frac{I_0}{2\omega} \frac{1}{(L/R_i) + C_1 R}.$$

Since this contains in the denominator the expression $\frac{L}{R_i} + C_1 R$ which we have designated by A, it is obvious that i_L changes suddenly at the same moment as i_2. It is noteworthy that the two values of i_L plotted against C_2 show no maximum except for $C_2 = 0$ and $C_2 = \infty$. This is seen in Fig. 10 in which the arrows show the order in which the curves are followed on increasing or decreasing C_2.

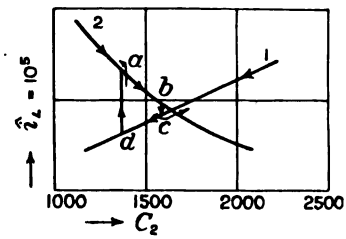

FIG. 10.

No reference has been made to energy

* W. Seitz, *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 460, 1920—see Abstract 1605, March, 1921.

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relations. This would require a more accurate assumption as to the valve characteristic, a consideration of the grid current and of the fact that the grid circuit has a natural period which may fall within the range here considered.

The object of the present paper was to show how the experimentally observed facts can be explained on the simplest assumptions.

Review of Radio Literature.

1. Abstracts of Articles and Patents.

(F.) Thermionic Valves (and Valve Apparatus).

(3) THEORY AND PHYSICS OF THERMIONIC VALVES.

1891. **L. C. Pocock.** Distortion in Thermionic Tube Circuits. (*Electrician*, 86, pp. 246—247, February 26th, 1921.)

In some uses of thermionic tubes as amplifiers there is little concern for faithful reproduction of the input waveform, yet for telephone amplification and similar purposes, distortion is a great disadvantage. This article discusses mathematically the distortion in such tubes arising in the grid and in the anode circuits, primarily through the variation of the impedance of the inter-electrode capacities with variation of the frequency of the input E.M.F. Distortion of the waveform of the input E.M.F. may arise from the non-linear nature of the tube characteristic if the amplitude is too great. A milliammeter in the plate circuit gives a useful indication of this distortion, as for minimum distortion there should be no change in its reading whether or not the alternating input E.M.F. is applied to the tube.

1892. **D. Owen and R. M. Archer.** The Quickness of Response of Current to Voltage in a Thermionic Tube. (*Proceedings of the Physical Society of London*, 33, pp. 104—115, February 15th, 1921.)

Steady voltages were applied between the hot and cold electrodes of a thermionic tube, for intervals of time which could be varied from 0·00001 second to a minute or longer. The mean current during the interval was measured by the Wheatstone bridge, using a null ballistic method. Both soft and hard valves were employed. The results point to the practical conclusion that in order to avoid phase difference between the current and the applied voltage, and consequent distortion at telephonic frequencies of signals transmitted through the tube, the vacuum should be as high as possible.

1893. **E. V. Appleton.** A method of Demonstrating the Retroactive Property of a Triode Oscillator. (*Proceedings of the Physical Society of London*, 33, pp. 100—103, February 15th, 1921.)

An approximate mathematical treatment (suggested by the work of Vallauri) is given of the conditions which give rise to retroaction between the grid and anode circuits of a triode valve, and expressions are given for the oscillation times of the circuit with and without retroaction. A simple lecture method of demonstrating the difference between these times is described. It consists in charging a condenser from a battery and discharging it through a coil included in the grid circuit of a triode. The natural frequency of the circuit is adjusted to be within the audible limits, and a marked difference is noticeable in the time during which the oscillation persists when the valve circuits are coupled and when they are separated.

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1894. **W. Schottky.** Back-coupling in Double Grid Valves with Anode Protective Grids. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, p. 51, January, 1921.)

Barkhausen has said that the danger of unavoidable back-coupling in amplifiers is greater with this type of valve than with the ordinary single grid type. Schottky states that by suitable design of the leads in the bulb and also of the socket, the capacity between the grid and anode circuits can be so reduced that there is no danger of self-excitation due to back-coupling.

1895. **G. Stead.** On the Design of Soft Thermionic Valves. (*Philosophical Magazine*, 41, pp. 470—482, March, 1921.)

An account is given of experiments which led up to the design of a satisfactory soft valve for naval uses. The chief points considered in the paper are: (1) The effect on the valve characteristic of the position of the grid with respect to the filament, and of the closeness of the grid structure. (2) The effect of the pressure and nature of the gas on the valve characteristics and on the production of oscillations. Nitrogen, argon, and helium were studied from this point of view, and it was found that there were serious objections to the first two gases, but that helium was very satisfactory. (3) A method of estimating the pressure of the gas in a sealed valve is given, and the effect of nitrogen and helium in cooling the filament by conduction and convection is considered.

1896. **A. Marcus.** Calculation of the Amplification Constant of the Weagant Thermionic Vacuum Tube. (*Physical Review*, 17, pp. 1—6, January, 1921. *Electrical World*, 77, p. 441, February 19th, 1921. *Technical Review*, 8, p. 142, February 8th, 1921—Abstract.)

The Weagant thermionic tube has the control electrode on the outside and because of the presence of the glass wall amplification is not possible for constant grid potentials. By making some simplifying assumptions, it has been found possible to develop a theoretical expression for the amplification constant which involves the dimensions of the tube and the resistivity of the glass wall. When the resistivity is either very high or very low, the amplification is small; in the latter case it is shown to depend solely on the dimensions.

1897. **W. Bragg.** Electrons. (*Journal of the Institution of Electrical Engineers*, 59, pp. 132—137, January, 1921. *Engineering*, 111, pp. 120—122, January 28th, 1921—Abstract.)

The full paper corresponding to abstract references No. 1595, March, 1921.

1898. **J. S. Townsend.** Collisions of Electrons and Molecules of a Gas: Distribution of Velocity of Electrons Moving under an Electric Force. (*Philosophical Magazine*, 40, pp. 505—511, October, 1920. *Science Abstracts*, 24A, pp. 128—129, Abstract No. 290, February 28th, 1921—Abstract.)

A criticism of Pedersen's method of calculating ionisation potentials. See RADIO REVIEW Abstract No. 800, September, 1920.

1899. **F. Horton and Miss A. C. Davies.** An Experimental Determination of the Critical Electron Velocities for the Production of Radiation and Ionisation on Collision with Argon Atoms. (*Proceedings of the Royal Society*, 97A, pp. 1—23, March 1st, 1920.)

1900. **F. Horton and Miss A. C. Davies.** The Effects of Electron Collision with Atmospheric Neon. (*Proceedings of the Royal Society*, 98A, pp. 124—146, October 1st, 1920.)

1901. **G. Breit.** The Calculation of Detecting and Amplifying Properties of an Electron Tube from its Static Characteristics. (*Physical Review*, 16, pp. 387—407, November, 1920; and 15, p. 553, June, 1920—Abstract. *Science Abstracts*, 24A, p. 218, Abstract No. 516, March 31st, 1921—Abstract.)

In the calculation of the detecting efficiency of an electron tube it is assumed that the static characteristics are available and that the constants of the circuits used with the tube are also known. From these quantities the average change in the plate current for a given amplitude of impressed grid voltage is derived. The input impedance is also calculated for the case of both positive and negative grid voltages. The amplification due to a single tube is given by the expression

$$\xi = \frac{1}{\frac{1}{r_p} + \frac{1}{(1/jC_{12}\omega)}}$$

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where r_p is the internal resistance C_g is the grid-plate capacity and $\omega/2\pi$ is the frequency. The majority of the formulæ derived are too complex to be abstracted.

1902. **E. O. Hulburt and G. Breit.** The Detecting Efficiency of the Single Electron Tube. (*Physical Review*, 16, pp. 408—419, November, 1920; and 15, pp. 552—553, June, 1920—Abstract. *Science Abstracts*, 24A, pp. 218—219, Abstract No. 517, March 31st, 1921—Abstract.)

Reference is made to an earlier paper on the detecting efficiency of the electron tube amplifier.* In the present paper the detecting efficiency of a single tube is investigated, theoretically and experimentally. If the grid potential E_g is given by $A \cos \omega t$ then it is found that the detecting efficiency

$$= \frac{r_p^2 \frac{\partial^2 I_p}{\partial E_g^2}}{4\left(1 + \frac{R_0}{r_p}\right)[(R_p + r_p)^2 + X_p^2]}$$

where I_p is the plate current, R_0 is the D.C. resistance of the plate circuit, R_p is the resistance of the plate circuit at frequency $\omega/2\pi$, X_p is the reactance of the plate circuit at frequency $\omega/2\pi$, and r_p is the internal resistance of the tube, and where the derivative $\partial^2 I_p/\partial E_g^2$ is taken with the assumption that E_p is kept constant and is to be evaluated for values of E_p and E_g when $A = 0$.

The formulæ for detecting efficiency were tested by inserting an inductance shunted by a variable condenser in the plate circuit of the tube thus making R_p large. Qualitative agreement with the formulæ was then shown and it was found that exact agreement could not be obtained unless the internal capacities of the tube were taken into account. The sudden drop in signal strength observed sometimes with Armstrong's tuned plate circuit is explained by the theory in the paper.

1903. **E. O. Hulburt and G. Breit.** The Detecting Efficiency of the Electron Tube Amplifier. (*Physical Review*, 16, pp. 274—281, October, 1920; 15, pp. 551—552, June, 1920—Abstract.)

A paper read before the American Physical Society in which it was shown that the general problem of investigating the behaviour of an amplifier requires consideration of two other problems, firstly the action of the amplifier itself and secondly the effect of the reaction between the amplifier and the external input circuit. The first is termed the problem of detecting efficiency, and the second that of the input impedance. The paper deals particularly with the detecting efficiency of the amplifier. Experiments were arranged to effect measurements of the input and output currents of a three-valve high-frequency transformer coupled amplifier. The experimental values of the detecting efficiencies were measured for various wavelengths and the amplification due to each tube of the amplifier was measured. It was found that the sound intensity in the telephones was increased in the ratio of 1,000 to 1 owing to the use of the first three tubes.

1904. **C. Davisson and H. A. Pidgeon.** The Emission of Electrons from Oxide-coated Filaments. (*Physical Review*, 15, pp. 553—555, June, 1920.)

A tungsten or other metallic filament coated with only a very minute quantity of barium oxide exhibits when heated thermionic activity comparable with that of oxide filaments coated in the usual way. Measurements on such a thinly-coated filament are described in the paper. The results show that the maximum emission occurs when the number of molecules deposited on the metal filament is not more than 30 per cent. of the number required to form a layer one molecule deep.

1905. **F. L. Mohler and P. D. Foote.** The Ionisation and Resonant Potentials of Nitrogen, Oxygen and Hydrogen. (*Physical Review*, 15, pp. 555—556, June, 1920.)

Abstract of a paper read before the American Physical Society. The results obtained are set out in tabular form.

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* RADIO REVIEW Abstract No. 1903.

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1906. **L. M. Hull.** Operation of an Electron Tube as an Amplifying Receiver. (*Physical Review*, 15, pp. 557—559, June, 1920.)

Abstract of paper communicated to the American Physical Society.

Expressions are derived for the rectification and amplification given by a three-electrode tube for two conditions of operation as a detector—when rectification is obtained by (1) utilising the curvature of the grid-current characteristic and (2) by utilising the curvature of the plate-current characteristic the main grid voltage being maintained at a negative voltage value by means of a battery. The effects of the tubes upon the receiving circuit are considered separately.

1907. **R. D. Duncan.** Stability Conditions in Vacuum Tube Circuits. (*Physical Review*, 17, pp. 302—314, March, 1921.)

After reviewing the fundamental requirements for the production of sustained oscillations in three-electrode vacuum tube circuits, the fundamental equation for the plate current of a tube with a linear volt-ampere characteristic is differentiated and an expression obtained giving a general relation between the constants of any oscillating circuit. This expression is evaluated for five standard types of circuit—the Hartley circuit, the Colpitt's circuit, the Meissner circuit and circuits having a tuned plate and a tuned grid. It is experimentally verified for the first two.

1908. **I. G. Barber.** Secondary Electron Emission from Copper Surfaces. (*Physical Review*, 17, pp. 322—338, and p. 393, March, 1921.)

Experiments are described for measuring the emission of secondary electrons from a copper surface bombarded by electrons. The method used was to measure the current flowing to the bombarded plate as a function of the grid potential. The coefficient of secondary emission was found to increase somewhat with the energy of the primary electrons up to 500 volts. The coefficient was increased by heat treating of the plate and was greatly decreased by raising the temperature of the plate. The shape of the curves obtained indicates that the secondary electrons have not been reflected from the plate.

1909. **J. G. Frayne.** The Dynamic Characteristics of Three-electrode Vacuum Tubes. (*Physical Review*, 17, pp. 391—393, March, 1921.)

Abstract of paper presented to the American Physical Society. Expressions are derived for the fundamental and harmonic components of the plate current by means of van der Bijl's expression for the dynamic characteristics when a resistance is included in the plate circuit. Measurements of these harmonics have been made, and they were found to agree in general with the theoretical values. The results show that the assumption that the static and dynamic equations are identical must be true.

Similar measurements were also made with an inductance included in the plate circuit. The experimentally-determined amplitudes were of the same numerical order of magnitude as those predicted by the equations for this case. Similar mathematical solutions for the cases when various combinations of resistance capacity and inductance are used are promised in the complete paper to be published later.

1910. **O. Koppius.** A Comparison of the Thermionic and Photoelectric Work Function from Platinum. (*Physical Review*, 17, pp. 395—397, March, 1921.)

1911. **K. T. Compton and P. S. Olmstead.** Note on the Radiating and Ionising Potentials of Hydrogen. (*Physical Review*, 17, pp. 45—53, January, 1921.)

1912. **F. L. Mohler and P. D. Foote.** Electron Currents in some Non-metallic Vapours. (*Physical Review*, 15, pp. 321—322, April, 1920.)

1913. **C. Davisson and L. H. Germer.** The Emission of Electrons from Oxide-coated Filaments under Positive Bombardment. (*Physical Review*, 15, pp. 330—332, April, 1920.)

Curves are given summarising the results of experiments on the emission from oxide-coated filaments. It is shown that in well-exhausted tubes the secondary emission under positive bombardment is in general less than $\frac{1}{100}$ of 1 per cent. of the thermionic emission.

1914. **F. Horton and Miss A. C. Davies.** Note on the Resonance and Ionisation Velocities for Electrons in the Monatomic Gases. (*Physical Review*, 15, pp. 498—504, June, 1920.)

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(4) AND (5) DESIGN AND CONSTRUCTION OF VALVES; AND TESTS AND MEASUREMENTS ON VALVES.

1915. **H. Mignet.** The Manufacture of Three-electrode Vacuum Tubes by an Amateur. (*La T.S.F. Moderne*, 1, pp. 221—232, October, 1920; pp. 261—274, November, 1920; pp. 303—312, December, 1920; and 2, pp. 14—21, January, 1921.)

Full details are given as to the construction of the apparatus necessary for easily building three-electrode valves.

1916. **The Connecticut Telephone and Electric Company.** Rectifier. (*French Patent* 500376, June 4th, 1919. Published March 10th, 1920.)

In a vacuum tube rectifier the anode is mounted outside the valve. The anode is of non-polarising material and the grid is in the form of a spiral surrounding the filament.

For further particulars see RADIO REVIEW Abstract No. 79, December, 1919.

1917. **V. J. F. Bouchardon and M. A. Lesage.** Valve Construction. (*French Patent* 502628, August 14th, 1919. Published May 21st, 1920.)

The specification describes a construction of grid for three-electrode valves. The grid is constituted by two parallel toothed rings braced by a number of metal rods, and a thin metal wire forming a continuous winding over the rings and accommodated in the notches.

1918. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Valve Construction. (*French Patent* 503385, August 30th, 1919. Published June 9th, 1920.)

The grid is in the form of a wire wound around a frame and interposed between the cathode and the anode. The cathode consists of a straight or V-shaped filament. See also *British Patent* 147616, of July 8th, 1920. Convention date March 20th, 1914. (British Thomson-Houston Company, assignees of **W. C. White.**)

1919. **General Electric Company, U.S.A.** (British Thomson-Houston Company). Anodes for Vacuum Tubes. (*British Patent* 143630, February 26th, 1919. Patent accepted May 26th, 1920.)

It is proposed to construct the anodes of rectifying and similar valves of an alkali metal such as an alloy of one part of sodium to two parts of potassium by weight. The container may be of glass and may be exhausted or may contain argon, hydrogen or other inert gas.

1920. **V. J. F. Bouchardon and M. A. Lesage.** Relay. (*French Patent* 504849, July 2nd, 1918. Published July 17th, 1920.)

The specification describes a vacuum tube relay containing an incandescent filament and a cold anode. A metal cylinder encircles the tube and variations in the potential of the cylinder cause a variation of the electronic current which is established between the filament and the anode.

1921. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Rectifier. (*French Patent* 506212, November 18th, 1919. Published August 17th, 1920.)

The incandescent cathode, grid and anode are so spaced in the tube that with a definite potential applied to the grid, the current between the anode and cathode varies proportionately with the anode potential over a definite range. The arrangement may be used with a continuous current ammeter for measuring alternating voltages applied to the anode circuit through a transformer connected in series with the ammeter.

There is a corresponding British Application No. 147819, of July 9th, 1920 (British Thomson-Houston Company, assignees of **W. C. White.** Convention date October 31st, 1917) the patent on which has not yet been granted.

1922. **Le Matériel Téléphonique.** Relay. (*French Patent* 506580, February 10th, 1915. Published August 25th, 1920.)

The relay is of the "audion" type and the novel feature consists in separating the hot cathode and the grid by a space only just sufficient to insulate them, so that a large amplifying ratio is obtained. For further particulars see *British Patent* 1694/1915.

1923. **Le Matériel Téléphonique.** Relay. (*French Patent* 506893, February 10th, 1915. Published August 31st, 1920.)

Two unidirectional thermionic valves are connected in such a manner that each amplifies

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one half of the wave. The two valves may be combined in a single structure having one heated cathode. For further particulars, see *British Patent* 275/1915.

1924. **E. M. Terry and C. M. Jansky.** The Construction of Three-element Power Electron Tubes. (*Physical Review*, 15, p. 142, February, 1920.)

A short note *re* a new pattern of three-electrode valve. Further particulars are promised later.

1925. **M. Kimura and J. Nagahata.** Unilateral Conductivity of Tubes having a Salt Electrode. (*Memoirs of the College of Science, Kyoto (Japan) Imperial University*, June, 1920. *Electrical World*, 77, p. 441, February 19th, 1921.)

An examination of the conditions of rectification in vacuum tubes having coated electrodes and an explanation of the process of the action.

1926. **S. L. Brown and C. E. Normand.** Characteristics of Vacuum Tubes. (*Physical Review*, 16, p. 365, October, 1920.)

Abstract of a paper contributed to the American Physical Society. The results of measurements on six different patterns of three-electrode valves are summarised in tabular form.

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(6) APPLICATION TO GENERATION OF OSCILLATIONS.

1927. **F. Harms.** Theory of Coupled Oscillatory Circuits with Triode Generators. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 442—457, June, 1920. *Technical Review*, 7, p. 290, November 30th, 1920—Abstract. *Science Abstracts*, 23B, p. 445, September 30th, 1920—Abstract. *Radioélectricité*, 1, p. 59D, November, 1920—Abstract.)

See pp. 313—322, in this issue for abstract.

1928. **W. C. White.** Electron Power Tubes and some of their Applications. (*General Electric Review*, 23, pp. 514—526, June, 1920. *Electrical World*, 76, pp. 536—537, September 11th, 1920—Abstract. *Science Abstracts*, 23B, p. 444, Abstract No. 846. September 30th, 1920—Abstract. *Radio News*, 2, pp. 204—205, October, 1920, *L'Elettrotecnica*, 8, pp. 14—15, January 5th, 1921—Abstract. *Revue Générale de l'Électricité*, 9, pp. 58D—59D, February 19th, 1921—Abstract.)

A full exposition is given of the factors of design and construction that determine the output of three-electrode valves for transmitting purposes. These include :—

(1) Dissipation of energy in the form of heat at the anode, which causes deterioration of the vacuum.

(2) Insufficient electron emission, resulting in a definite limitation of the anode current and of the energy input to the tube.

(3) Insufficient exhaust.

(4) Insufficient dielectric strength in the materials holding the electrodes and in the lead-in wires and terminals.

(5) Insufficient mechanical strength to withstand the mechanical force due to electrostatic fields.

(6) Improper geometrical design or construction.

The properties of oscillating circuits suitable for high-power tubes are discussed and illustrated. Descriptions are given of various forms of valve transmitting units using as many as thirty tubes in parallel.

1929. A Tube Set operated on A.C. without Rectification. (*Everyday Engineering Magazine*, 10, pp. 62—63, October, 1920.)

Details are given of a valve transmitter designed by the Bureau of Standards.

1930. **W. C. White.** Some Practical Operating Features of Tungsten Filament Electron Tubes. (*General Electric Review*, 23, pp. 840—846, October, 1920.)

This article discusses some of the unusual effects which often occur in the experimental operation of valve transmitting apparatus. These are considered under the following headings : The Filament ; The Grid ; The Plate or Anode ; Bulb and Glass ; Vacuum Conditions ; Vacuum Tube Circuits and their Operation ; Power Supply. A number of practical hints are given.

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1931. **Le Matériel Téléphonique.** Continuous Wave Transmitter. (*French Patent* 503718, September 11th, 1919. Published June 16th, 1920.) Also **Western Electric Company.** (*British Patent* 152811, August 7th, 1919.)

The system described is one employing a thermionic oscillation generator and a thermionic modulator for modulating oscillations in accordance with the low-frequency signal fluctuations. The three electrodes of the generator are connected to points of different potential in the aerial circuit, so that the frequency generated is primarily determined by the constants of that circuit. For instance both the anode and grid of the valve may be connected to tapping points on the aerial tuning inductance (the latter through a blocking condenser), the valve filament being earthed and a condenser being connected between the lower end of the aerial tuning inductance and earth. The " choke " control method of modulation is shown in the circuit diagrams.

1932. **Le Matériel Téléphonique.** Continuous Wave Transmitter. (*French Patent* 505108, September 11th, 1918. Published July 23rd, 1920.)

In transmitting apparatus in which the oscillations are generated by a thermionic generator, the signal producer, for example a microphone or an amplifier of the microphone current, is connected across the battery and choke coil supplying current to the plate circuit of the generator. For further particulars see *British Patent* 133366.*

1933. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Continuous Wave Transmitter. (*French Patent* 506979, April 10th, 1919. Published September 2nd, 1920.)

For the production of currents of two or more frequencies one or more of which may be audible and the others of radio frequency, a three-electrode vacuum tube is employed in the manner indicated in Fig. 1, which shows the arrangement for the generation of radio frequency currents having an audible group frequency. The circuit $L_1C_1L_2C_2$ is tuned to the radio frequency, and the circuit $L_3C_3L_4C_2$ to the audio frequency. G is the H.T. generator supplying the plate circuit. For further particulars see *British Patent* 152365.

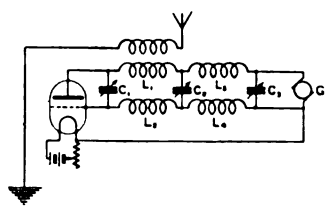

FIG. 1.

1934. **G. Leithauser and K. Heegner.** The Production of Alternating Current by means of Two Triodes. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, pp. 21—39, January, 1921. *Verhandlungen der deutschen Physikalischen Gesellschaft*, 1, p. 89, December 31st, 1920.)

A study of methods of generating A.C. in which the phase of the anode P.D. of the first valve has to be reversed in the second valve before back-coupling to the grid of the first valve. The coupling between the first anode and second grid is by means of anode resistance or reactance and a grid tapping through a condenser; the back coupling from the second anode to the first grid is by pure capacity, *i.e.*, two condensers in series, tapped off to the grid from their junction point. The circuits are investigated mathematically and their advantages discussed.

1935. **E. Takagishi.** Behaviour of a Three-electrode Vacuum Tube as an Oscillation Generator. (*Electrician*, 86, pp. 346—348, March 25th; pp. 374—375, April 1st, 1921.)

A mathematical study of the generation of oscillations with a three-electrode tube from the standpoint of the dynamic characteristics. It is pointed out that the derived characteristics can be obtained from the constants of the circuits with which the tube is used; and equations are developed for the oscillation current, power output, etc. Experimental measurements confirming the theory are set out in detail with curves.

1936. **J. Scott-Taggart.** The Production of Continuous Oscillations in Circuits which contain Capacities of High Value. (*Electrical Review*, 88, pp. 7—8, January 7th, 1921.)

In order to overcome the difficulty frequently experienced with a three-electrode valve

* RADIO REVIEW Abstract No. 338, May, 1920.

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arranged for oscillation generation that the oscillations cease when the capacity of the oscillation circuit is varied over a wide range, it is proposed to employ one or more amplifying valves to magnify the retroactive impulses from the anode back to the grid. Circuit diagrams are shown using one or two extra valves for this purpose, and a resistance is included in the anode circuit of the last amplifying valve to provide the necessary retroactive coupling back to the grid of the first or main oscillator valve.

1937. **J. Scott-Taggart.** A Vacuum Tube Oscillator. (*Wireless Age*, 8, p. 20, January, 1921.
Refers to the use of an ordinary three-electrode vacuum tube as a dynatron for generating continuous oscillations. (See also RADIO REVIEW, 2, p. 220, April, 1921.)

1938. **A. N. Goldsmith.** The Production and Control of Radio Frequency Oscillations. (*Wireless Age*, 8, pp. 19—20, December, 1920.)
An arrangement is described using six three-electrode valves for radiotelephonic transmission purposes, one being employed for oscillation generation, one for modulation by the constant current control method, one for low-frequency amplification of the microphone currents and three for high-frequency amplification of the modulated radio frequency currents.

1939. **E. J. Jones.** A Wireless Telephony Set. (*Wireless Age*, 8, pp. 23—26, December, 1920.)
Detailed constructional details are given.

1940. **J. Scott-Taggart.** Radiotelephony Systems employing Thermionic Vacuum Tubes. (*Wireless Age*, 8, pp. 17—18, January, 1921; pp. 17—19, February, 1921; pp. 21—23, March, 1921; and pp. 17—18, April, 1921.)
Descriptions are given of various modulation arrangements using three-electrode valves.

1941. **R. A. Heising.** A Vacuum Tube Transmitter. (*Wireless Age*, 8, p. 23, March, 1921.)
The modulation arrangement involves the use of a double grid tube for effecting the modulation of the high-frequency energy. Voltage impulses from the H.F. source are impressed upon one grid whilst the transmitting microphone is inductively coupled to the second.

1942. **R. Dubosq.** An American Wireless Telephone Installation. (*La T.S.F. Moderne*, 1, pp. 298—302, December, 1920.)
An illustrated description, giving details of the mode of construction.

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(7), (8) AND (9) MISCELLANEOUS APPLICATIONS OF TWO- AND THREE-ELECTRODE VALVES, AND ACCESSORIES FOR VALVE CONSTRUCTION (PUMPS, ETC.).

1943. **R. L. Smith-Rose.** Some Applications of Thermionic Valve Rectifiers. (*Beama Journal*, 7, pp. 567—571, June, 1920; pp. 20—24, July, 1920.)
Continues a previous description of the kenotron and its application to X-ray tubes and the measurement of peak voltages. The two-electrode valve is also discussed as a low-voltage rectifier. Many circuit diagrams and sketches of rectifying tubes are also included.

1944. **V. J. F. Bouchardon and M. A. Lesage.** Relay. (*French Patent* 503935, December 4th, 1917. Published June 21st, 1920.)
The specification describes an incandescent cathode relay which consists of a vacuum tube containing two electrodes (an incandescent filament and a cold anode) and a solenoid to produce a magnetic field, the said solenoid being excited by the incoming current. The field of the solenoid is employed to modify the trajectory or path of the electrons and cause a variation of the electronic current. A field produced by a continuous current is employed to give stability to the electron field.

1945. **S. Butterworth.** The Maintenance of a Vibrating System by means of a Triode Valve. (*Proceedings of the Physical Society of London*, 32, pp. 345—360, August 15th, 1920. *Nature*, 105, p. 842, August 26th, 1920—Abstract.)
The paper gives a mathematical analysis of an arrangement previously described by Dr. Eccles whereby vibrations of a tuning fork are maintained by means of a triode valve. The original should be referred to for details.

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1946. **R. Whiddington.** Wireless Valve Circuits as applied to the Measurement of Physical Quantities. (*Wireless World*, 8, pp. 739—745, January 22nd, 1921. *Electrical World*, 77, p. 611, March 12th, 1921—Abstract.)

Paper read before the Wireless Society of London on Tuesday, December 21st, 1920. See also RADIO REVIEW Abstract No. 1629, March, 1921.

1947. **A. Bailey.** An Improved Form of McLeod Gauge. (*Physical Review*, 15, pp. 319—320, April, 1920.)

1948. **S. Dushman and C. G. Found.** Studies with the Ionisation Gauge. I. Construction and Method of Calibration. (*Physical Review*, 17, pp. 7—19, January, 1921; also 15, pp. 133—134, February, 1920—Abstract.)

1949. **S. Dushman and C. G. Found.** Studies with the Ionisation Gauge. II. Relation between Ionisation Current at Constant Pressure and Number of Electrons per Molecule of Gas. (*Physical Review*, 15, pp. 134—135, February, 1920.)

1950. A New Form of High Vacuum Pump. (*Iron Age*, May 6th, 1920. *Technical Review*, 7, p. 389, December 21st, 1920—Abstract.)

A new form of high-vacuum pump not requiring oil immersion is described. The apparatus is designed to give a vacuum suitable for incandescent lamps, X-ray tubes, etc.

1951. **R. B. Wailes.** Production of High Vacua in the Laboratory. (*Experimental Science*, 1, pp. 53 and 62, August, 1920.)

A description of the Langmuir mercury vapour pump.

1952. **S. Dushman.** The Production and Measurement of High Vacua. (*General Electric Review*, 23, pp. 493—502, June; pp. 605—614, July; pp. 672—683, August; pp. 731—740, September; pp. 847—855, October, 1920; also 24, pp. 58—68, January, 1921; pp. 244—252, March; pp. 436—443, May, 1921.)

This article first discusses the fundamental principles of the kinetic theory of gases which are of importance in connection with the discussions of methods for production and measurement of high vacua, with which the remainder of the article deals in detail. Sections are devoted to the Number of Molecules per Unit Volume; The Rate at which Molecules Strike a Surface; Mean Free Path of Molecules; Molecular Diameters, including Tables of Molecular Diameters for various Gases; Laws of Molecular Flow; Laws of Flow at High Pressure; Thermal Molecular Flow. The various methods for the production of high vacua are classified, and illustrated descriptions are given of many different types of high vacuum pump. The measurement of high vacua is next considered and descriptions are given of different types of manometers including theoretical discussions of various methods of measuring high vacua. The types of manometers particularly considered are mercury manometers such as Rayleigh's gauge and the McLeod gauge; mechanical manometers; viscosity manometers; radiometer gauges—Crooke's radiometer, Knudsen's gauge and its modifications; resistance radiometers including the Pirani-Hale gauge; and ionisation gauges. The adsorption of gases by charcoal and palladium-black is also discussed, together with their use at very low temperatures for improving the vacuum in sealed-off tubes. A number of experimental results are included in the form of tables and curves of adsorption by charcoal. The composition and quantities of residual gases evolved by glass and metals *in vacuo* are discussed at length, and mechanical methods of removing these residual gases are also considered together with the electrical "clean-up" phenomena occurring at low pressures.

(G.) Transmitter Control or Modulation.

1953. **E. H. Shaughnessy.** The Use of a Spacing Wave in Continuous Wave Wireless Telegraphy. (*Post Office Electrical Engineers' Journal*, 14, pp. 30—32, April, 1921.)

Refers to the development of the Poulsen arc, and the use of a spacing wave for signalling with high-power arcs. Contrary to usual opinions, the use of a spacing wave is regarded as advantageous if the wavelength change is small (0·8 per cent. is mentioned as suitable for 15,000 metres wavelength), as its use introduces fewer harmonics and less disturbance of the æther than when the aerial circuit is keyed directly at high speeds. The disadvantages of using more power may be much more than outweighed by the possibility of crowding more stations into the total available zone of wavelengths.

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1954. **J. H. Hammond.** Hammond's Selective Receiver. (*Wireless Age*, 8, p. 18, November, 1920.)

A method of signalling which consists in varying the coupling between the primary and secondary of the transmitting jigger by rotating the primary coil relative to the secondary by means of an electromagnetically operated crank.

1955. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Continuous Wave Transmitter. (*French Patent* 506988, April 14th, 1919. Published September 2nd, 1920.)

The specification describes a wireless signalling system employing continuous waves in which amplitude pulsations of the oscillations in the antenna are produced by a series of alternating currents of different frequencies, of a lower order than the wave frequency.

For further particulars, see *British Patent* 128682. (RADIO REVIEW Abstract No. 30 November, 1919.)

1956. **J. Brun.** The Application of High-speed Telegraphic Apparatus to Radio Work. (*Radioélectricité*, 1, pp. 432—440, February; pp. 477—487, March, 1921.)

A good description is given of the arrangements that may be used, and includes a preliminary consideration of duplex working with high-power stations.

The arrangements of high and low-frequency amplifiers are described and the connection schemes given for coupling them to the relays necessary for operating the printing mechanism. The Wheatstone, Creed, and Baudot apparatus are described and illustrated.

1957. **L. Levy.** Secrecy Systems of Wireless Signalling. (*British Patent* 143583, August 2nd, 1918. Patent accepted June 3rd, 1920.)

A secrecy method of wireless signalling is described depending upon the use of a supersonic heterodyne, as well as an ordinary heterodyne for telegraphic signalling; and a similar method, with the omission of the lowest frequency heterodyne for telephonic work. The oscillations of the main transmitting valve are modulated by means of another valve oscillating at a supersonic frequency, and the signalling currents, whether telephonic or telegraphic, are impressed upon this medium frequency oscillator so as to modulate its output. Various arrangements of the receiving apparatus are also described.

1958. **E. S. Purington.** The Load on the Modulator Tube in Radio Telephony Sets. (*Physical Review*, 15, pp. 556—557, June, 1920.)

Abstract of a paper contributed to the American Physical Society in which it is pointed out that the load on the modulator tube in a radio telephone transmitter usually approximates to a resistance, but reactive components may arise through imperfections in the choke coil included in the H.T. supply circuit; through the use of a choke coil of high radio frequency reactance in series with the oscillating valve; and through the power necessary to change the electromagnetic energy associated with the antenna or oscillating circuits. The first of these three effects is usually the most important in short range telephone sets but the others become increasingly important with higher-powered installations.

1959. **R. A. Heising.** Heising's Modulator Method. (*Wireless Age*, 8, pp. 20—21, November, 1920.)

The arrangement consists essentially in the use of a valve amplifier between the modulating microphone and field windings of a high-frequency alternator used to supply the energy to the transmitting aerial.

1960. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Continuous Wave Transmitter. (*French Patent* 506982, April 10th, 1919. Published September 2nd, 1920.)

For the production of an electric wave of radio frequency, a source of alternating current of radio frequency is connected to the aerial through two parallel circuits containing magnetic controllers of a particular type. For further particulars, see *British Patent* 16443/1915.

1961. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Transmitter. *French Patent* 506983, April 12th, 1919. Published September 2nd, 1920.)

The specification describes a system for the control of high-frequency alternating currents such as are used in wireless signalling, in which a special form of magnetic controller is employed. The signalling or controlling windings of the controller are arranged to cover substantially the whole of the magnetic circuit of the high-frequency windings, which are so

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arranged that their inductive effect on the controlling windings is neutralised. In one form of the controller illustrated the high-frequency windings are wound separately on two parallel bars and are completely surrounded by the controlling winding. For further particulars, see *British Patent* 103842.

1962. **W. S. Tucker** and **E. T. Paris.** A Selective Hot-wire Microphone. (*Transactions of the Royal Society*, 221A, pp. 389—430, March 3rd, 1921.)

A description with an account of tests on the instrument.

1963. **The Magnavox Company.** Telephone Transmitter. (*French Patent* 499748, July 5th, 1918. Published February 20th, 1920.)

The specification describes a telephone transmitter.

1964. **Gesellschaft für drahtlose Telegraphie.** Circuit for Wireless Telephony. (*German Patent* 305027, September 1st, 1917. Patent granted January 13th, 1920. An addition to *Patent* 300783. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 306, October, 1920—Abstract.)

A "quiescent aerial" arrangement in which oscillations are only generated when the microphone is spoken into.

1965. **E. B. H. Wade.** Meniscus Microphones. (*Engineer*, 131, p. 442, April 22nd, 1921.)

Describes a special form of liquid microphone in which the resistance variations take place in an orifice 0·3 mm diameter in a glass tube just touching the surface of a liquid meniscus.

1966. Connecting Wire and Wireless Telephones. (*Elektrotechnische Zeitschrift*, 42, p. 160, February 17th, 1921.)

Refers to a connection established between a vessel in the Atlantic and the radio telephone exchange at Catalina Island.*

1967. **Long-distance Telephony.** (*Nature*, 107, pp. 241—242, April 21st, 1921.)

Refers to some long-distance wire telephone tests (5,500 miles), part of the route being the wireless link between Catalina Island and the mainland.

1968. **G. Valensi.** The Telephonic Relays of the Western Electric Company. (*Annales des Postes, Télégraphes et Téléphones*, 10, pp. 63—101, March, 1921.)

A description of various thermionic valve relay arrangements, with characteristic curves of the tubes, and a mathematical discussion of their conditions of operation.

1969. **E. W. Scripture.** Nature of Vowel Sounds. (*Nature*, 106, pp. 664—666, January 20th, 1921.)

A continuation of an earlier article—see RADIO REVIEW Abstract No. 1647, April, 1921. The artificial manufacture of vowel sounds by means of a puff syren is described; while the remainder of the article is devoted to a study of the structure of vowel sounds and includes formulæ for representing the wave forms.

1970. **H. Fletcher.** The Relative Difficulty of Interpreting the Spoken Sound of English. (*Physical Review*, 15, pp. 513—516, June, 1920.)

An investigation of the errors in the interpretation of speech sounds which were transmitted over an electrical system including thermionic valve amplifying apparatus. The results are given in the forms of tables and curves.

(H.) Radio Receiving Apparatus.

(1) GENERAL ARTICLES ON RECEIVING APPARATUS.

1971. **F. O. Read.** A Short Wave Receiver. (*Wireless World*, 8, pp. 477—478, October 2nd, 1920. *Technical Review*, 7, p. 358, December 14th, 1920.)

1972. A New Receiving Arrangement. (*Radioélectricité*, 1, pp. 57—58, June, 1920. *Telegraphen- und Fernsprech-Technik*, 9, pp. 96—97, August, 1920.)

Refers briefly to tests of a new receiver developed by the *Société Française Radioélectrique*, with which it is claimed that transatlantic messages can be received and photographically recorded without the use of any aerial (antenna, or frame) external to the apparatus itself. Sample records are reproduced. Simultaneous reception of a number of stations can be

* See RADIO REVIEW Abstract No. 1060, November, 1920.

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effected if the wavelengths differ by more than 2 per cent. Judging from the photographic illustration nine valves are apparently used. Almost perfect freedom from atmospheric interference is claimed.

(See also RADIO REVIEW, pp. 130—132, March, 1921, where further reference is made to the use of this receiving apparatus.)

1973. **M. Adam.** Time Signal Reception. (*Radioélectricité*, 1, pp. 97—101, July, 1920.)
Describes several simple forms of receiving apparatus.

1974. **M. Adam.** The Adjustment of Receiving Aerials. (*Radioélectricité*, 1, pp. 148—153, August; pp. 205—210, September, 1920.)

1975. **M. Adam.** The Reception of Damped Waves. (*Radioélectricité*, 1, pp. 262—266, October, 1920.)

1976. **P. Maurer.** Wireless Receiving Circuits. (*L'Électricien*, 52, pp. 151—153, April 1st, 1921.)
The main forms of simple receiving circuits are outlined.

1977. **C. G. Crawley.** Wireless Reception. (*St. Martin's le Grand*, 31, pp. 69—74, April, 1921.)
A popular article covering similar ground to that referred to in Abstract No. 1081, November, 1920.

1978. **A. A. Isbell.** Radio Taste Reception. (*Annales des Postes, Télégraphes et Téléphones*, 10, p. 187, March, 1921.)
Refers to similar experiments to those described in Abstract No. 1379, January, 1921.)

1979. **J. G. Reed.** Lighting Valve Filaments with A.C. (*Sea, Land and Air*, 3, pp. 124—126, May, 1920.)
Constructional details are given for the necessary transformers.

1980. **J. G. Reed.** Long Wave Receivers. (*Sea, Land and Air*, 3, pp. 682—684, January, 1921.)
Abstract of lecture delivered before the Wireless Institute of Australia, and giving constructional and design details for receiving apparatus.

1981. The Universal Wavelength Receiver. (*Wireless Age*, 8, pp. 26—27, November, 1920.)
A simple form of receiver is described in which the various coils are placed in circuit by means of telephone plugs and jacks.

1982. **H. S. Pyle.** A Sensitive and Compact Multiple Receiver. (*Wireless Age*, 8, p. 22, December, 1920.)

1983. **G. N. Garrison.** Efficient Design of Regenerative and Amplifier Circuits. (*Wireless Age*, 8, pp. 21—22, January, 1921.)

1984. **H. Riegger.** Reception of Electric Waves. (*German Patent* 297935, June 16th, 1914. Patent granted December 10th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 153, August, 1920—Abstract.)
A two-circuit receiver with large coefficient of coupling K, natural frequencies N_2 and N_3, and decrements δ_2 and δ_3. The values of these constants are so arranged that if N is the frequency of the sending station the following relations hold

$$\frac{N_2^2}{N^2} - 1 = -\frac{1}{\pi}\sqrt{\frac{\delta_2}{\delta_3}(\pi^2K^2 - \delta_2\delta_3)}$$

$$\frac{N_3^2}{N^2} - 1 = -\frac{1}{\pi}\sqrt{\frac{\delta_3}{\delta_2}(\pi^2K^2 - \delta_2\delta_3)}.$$

1985. **H. Abraham.** On Recent Progress in the Reception of Long Range Wireless Signals. (*Bulletin de la Société Française des Électriciens*, 10, pp. 387—395, November, 1920.)
The full paper to which reference has been made in RADIO REVIEW Abstract No. 1384, January, 1921.

(3) SPECIAL ELECTRON-TUBE DETECTORS AND RECEIVERS.

1986. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Valve Detector. (*French Patent* 506984, April 12th, 1919. Published September 2nd, 1920.)
A receiving circuit is connected to a vacuum tube having a negative resistance. The

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vacuum tube is connected in series with a battery and telephone across the condenser of the resonant receiving circuit. For further particulars, see *British Patent* 114539.

1987. **J. Scott-Taggart.** Some New Circuits for Radiotelegraphy employing a Double Grid Vacuum Tube. (*Electrician*, 86, pp. 87—98, January 21st, 1921.)

A description is given of a double grid vacuum tube designed by the writer of the article (*British Patent* 153681). The application of this valve to the amplification of low-frequency impulses and the reception of continuous waves is discussed in the article and circuit diagrams are given for three different arrangements. The incoming oscillations are applied between the filament and one of the grids, while the second grid may be employed for a retroactive coupling for further amplification or for the generation of heterodyne oscillations. In the latter case the circuit is practically non-radiating.

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2. Books.

ADMIRALTY HANDBOOK OF WIRELESS TELEGRAPHY, 1920. (London: *H.M. Stationery Office*. 1920. Pp. viii + 477. $9\frac{1}{4}'' \times 6''$. Price 7*s*. 6*d*. net.)

It is usual for elementary books on wireless telegraphy to contain a few preliminary chapters on electricity and magnetism by way of introduction to the subject. These are usually too brief for the uninitiated to gather any real knowledge of the subject, and so elementary as to be useless to those already possessing some electrical knowledge.

This statement cannot, however, be made of the "Admiralty Handbook of Wireless Telegraphy, 1920," in which the remedy has been taken of increasing the preliminary portion to such an extent that over two-fifths of the book is devoted to general electrical engineering.

The work commences with an elementary discussion of sound and æther waves, and the theory of electricity and magnetism is introduced immediately by way of the electronic constitution of matter; a point of importance in view of the wide use of thermionic valves at the present time. The laws of electricity and magnetism are then dealt with, and the units involved and the principles of measuring instruments are described. Further chapters deal in a very complete manner with the essential principles of electromagnetic generators of both direct and alternating currents, and a chapter is given on transformers. No mathematical theory is introduced but all the fundamental formulæ for making calculations are given and their use well illustrated by a liberal sprinkling of numerical examples throughout the text.

Turning to the more wireless portion of the book, this deals in a very clear though elementary manner with the generation of electrical oscillations and the radiation of electromagnetic waves for wireless signalling purposes. Without mention of any particular system, it deals with the various methods of generating both damped and undamped oscillations, emphasising the advantage of the latter. For the receiver, the various types of rectifying detectors are described, and the circuit arrangements in which they may best be used. A novel feature of this chapter, at least so far as the writer is aware, is the graphical explanation of the action of a rectifier on a train of damped oscillations, by the method so often adopted for valve circuits.

The valve is introduced from the standpoint from which it first found use in the Navy, viz., as a feeble generator of oscillations for heterodyne reception. The applications as rectifier and amplifier are then described giving the various typical circuit arrangements which may be employed. Finally a chapter is given on a complete modern transmitting valve circuit, illustrating the functions of the various parts of apparatus used. A distinctive feature of these "valve" chapters, is that all explanations are given very clearly by the aid of diagrams which are presumably actual, and not hypothetical, characteristic curves. The co-ordinates of these characteristics are marked off in the correct units, an important feature in conveying an idea of the magnitude of the quantities involved, such as, *e.g.*, the relative strengths of anode and grid currents.

The chapter on radiotelephony is rather short, particularly in view of the probable large development of this branch for short range communication in the naval and air services. A fundamental idea of the propagation of electromagnetic waves and the influence of the earth and the atmosphere is conveyed by a chapter on "The Æther and the Atmosphere." The book concludes with three very good and practical chapters on "Aerials and Earths," "Wave-

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meters," and "Care and Maintenance of W/T Installations," which should be found particularly useful to the operator in charge of a ship's wireless set. Some notes on mathematics and mechanics for the elementary student, and a number of useful tables and formulæ are given as appendices.

Altogether the book is an excellent description of the principles of wireless telegraphy, presented in a good style with few misprints. The text is liberally interspersed throughout with a large number of extremely clear and accurate diagrams. An improvement in this direction might have been achieved by the introduction of a few photographs of typical apparatus, or at least some more line drawings, such as that of an armature on p. 96, or the receiving valves on p. 292, which serve to give a more concrete idea of the apparatus described.

The chief fault of the book lies with the index, which is neither full enough, nor arranged to the best advantage. The principle adopted here, of giving references to paragraphs instead of to pages is a bad one, particularly when the paragraph numbers in the text are not emphasised by heavy type. As an example of bad indexing, that of paragraph 474 may be noted. This paragraph deals with the radiation of waves and the term wavelength is illustrated by a diagram, the symbol λ, not being mentioned for the first time. The reference to this paragraph, however, is to be found under "Lambda," and not under "Wave," or "Wavelength."

As a service handbook it is notably free from any reference to service apparatus, and descriptions of sets of the "M C 2" variety, with which such handbooks are usually filled. Although it is naturally written for the use of naval ratings, and one or two terms are introduced which are not in general use outside the service, it forms one of the best up-to-date text-books on wireless available at the present time. It can well be recommended to the general student and at the price of publication it is very cheap. It is rather to be regretted that no names are mentioned in the book, as the work undoubtedly reflects great credit upon the author or authors responsible for its production. A last commendable feature of the book is that the symbols used throughout are in accordance with the adoptions of the International Electrotechnical Commission.

R. L. SMITH-ROSE.

HET DRAADLOOS ZENDSTATION VOOR DEN AMATEUR (TELEGRAFIE EN TELEFONIE). By J. Corver. ('s-Gravenhage: *N. Veenstra*. 1920. Pp. 106. $9\frac{1}{2}'' \times 6\frac{1}{4}''$. Price not stated.)

This book contains a non-mathematical account of the various transmitting systems, old and new, from the point of view of the experimental amateur. Freehand sketches are given showing how the various pieces of apparatus may be constructed. When the use of a few mathematical symbols is unavoidable, as in dealing with the calibration of a wavemeter, the matter is put in small type as an appendix to the chapter.

The first system described is the buzzer transmitter; this is followed by a description of the Ruhmkorff coil and its use first with a plain aerial, and then with a coupled aerial. Wavelength, logarithmic decrement and the effects in coupled oscillatory circuits are described in very simple language, and with the help of mechanical analogies. Fundamental and harmonic oscillations of aerials and solenoids are described and illustrated. Several chapters are then devoted to valve transmitting systems, and the heterodyne wavemeter is also described. Two chapters are devoted to radiotelephony transmitters, and in the concluding chapter the question of earthing is discussed, and also measurements to be made on the antenna, its effective height, radiation resistance, and the efficiency of the antenna as a radiator of energy.

The book will doubtless be of use to Dutch amateurs. The author is a frequent contributor to *Radio Nieuws*, the organ of the wireless amateur movement in Holland.

G. W. O. H.

Book Received.

ELECTRICITY AT HIGH PRESSURES AND FREQUENCIES. By H. L. Transtrom. (Chicago: *The Joseph G. Branch Publishing Co.* Second Edition. 1921. Pp. xi + 247. $7\frac{1}{4}'' \times 5''$. Price $2.50.)

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Correspondence.

"THE HETERODYNE METHOD OF WIRELESS RECEPTION, ITS ADVANTAGES, AND ITS FUTURE."

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In reply to M. Latour's letter and the mistake No. 1 which he states I have made, I will quote one part of my own letter :—

"About the simplest method of modulation is to transmit simultaneously with two wavelengths say from two C.W. stations near to one another. If the wavelengths are separated by a frequency n, then a receiver without a heterodyne at a distance will hear a musical note of frequency n. If one of these stations stops sending Morse and makes a long dash, at the receiving end no difference will be noted as far as the signals are concerned. X's will, however, be slightly altered by the action of the dash from the one transmitter during the spacing intervals. *It can, however, be easily imagined that this dash cannot seriously affect the X, particularly when the signal is weak.* Consequently there is no apparent difference between the two methods of sending.

"Now the receiver could not tell if this dash sent by the one C.W. station were replaced by a heterodyne at the receiving station giving the same current and frequency to the receiving aerial particularly if the heterodyne were arranged to simulate direction as well as strength and frequency. So that obviously the modulation which M. Latour suggests is a property of the transmitting station resolves itself into a clumsy way of heterodyning—without several of the good properties of the heterodyne."

I have marked in italics one particular sentence. I think sufficient justification exists for this sentence as we are hardly discussing the cases of X's and signals when the former are equal to or of less value in instantaneous current than the latter and unless the heterodyne has at least a strength equal to the instantaneous value of the X, the magnification of the X is quite small (see paper by Edwin H. Armstrong presented before the Institute of Radio Engineers, New York, October 4th, 1916), even in the case when a very resonant note amplifier is in use like M. Latour's devices.

Admitted that with the second wave of the transmitter now replaced by the heterodyne, and the latter strengthened up to the optimum value, there is a great strengthening up of X's in the space, *but the signal is at least proportionately strengthened.*

M. Latour's argument that I have made a mistake in case No. 2 also falls to the ground.

Suppose we assume he is receiving his modulated wave made up with two transmitters, transmitting f_1 and f_2, and he is tuned to $\frac{f_1 + f_2}{2}$, what is the decrement of his aerial system ? On that will depend the spectrum of the result of his X and his signal acting on one another. (I will leave out the fact that this is not the only action of the X.) He makes a serious mistake in assuming the result of the X is a note of $\frac{f_1 - f_2}{2}$. It is a damped oscillation with a period $\frac{f_1 - f_2}{2}$ which can act on the note circuit tuned to $f_1 - f_2$. The nearer and nearer the X is turned into a pure note $\frac{f_1 - f_2}{2}$ the less will be its action on the circuit tuned to $f_1 - f_2$, but to obtain this result the lower and lower his aerial damping will have to be made, and that means that the mistuning of his aerial system (for his signal is of frequency f_1 and f_2 while his aerial is tuned to $\frac{f_1 + f_2}{2}$) will have more influence on the ratio between the value of the signal received and what could be received if the signal wave and aerial system were in tune.

So that again, although M. Latour has dodged the X at its maximum, he has also obtained proportionately weaker signals.

I think even if M. Latour does not accept this last argument quantitatively, he must admit that by choosing a weak heterodyne of frequency f_2 and retaining all his tunings the same as before, he can produce the same result as if the second transmitter f_2 were in actual use.

H. J. ROUND.

London. *May 17th*, 1921.

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Assistant Editor:
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THE
RADIO REVIEW

VOL. II JULY, 1921 NO. 7

Double-grid Valves.

By THE EDITOR

In an ordinary three-electrode valve with a single grid the plate current depends on both the plate voltage V_p and the grid voltage V_g. This relationship can be expressed by the equation

$$I_p = f(V_g + DV_p) = f\left(V_g + \frac{V_p}{\mu}\right)$$

in which the current is expressed as a function of an effective control voltage made up of the grid voltage and a fraction $D = \frac{1}{\mu}$ of the plate voltage. German writers usually employ the fraction D to express the relative importance of a given change of voltage on the grid and plate respectively; in this country and in the United States the whole number $\mu = \frac{1}{D}$ is more often used and is known as the amplification factor or voltage ratio. In either form it is a measure of the extent to which the grid screens the filament from the action of the plate or anode. This is clearly expressed in the German "Durchgriff," the through-grip or extent to which the anode voltage penetrates the openings in the grid and acts on the electrons emitted from the filament. A valve is thus said to have a "Durchgriff" of 5 per cent. or an amplification factor of 20. If the grid has large openings D will be large and μ small; if the openings in the grid are small, it will more effectively screen the filament from the action of the plate voltage, D will be small and μ large.

If the plate current be kept constant by decreasing V_p as V_g is increased, μ is equal to the ratio $-\frac{\partial V_p}{\partial V_g}$. If V_g be kept constant a change of plate voltage ∂V_p produces a change of plate current ∂I_p and the ratio $R_i = \frac{\partial V_p}{\partial I_p}$ is called the internal resistance of the valve to an oscillatory current in the plate circuit. The slope S of the ordinary characteristic curve of the valve is equal to the ratio $\frac{\partial I_p}{\partial V_g}$, V_p being kept constant. These three charac-

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teristic constants of the valve are connected by the relation

$$\mu = S \cdot R_i.$$

If the valve be used as an amplifier with a non-inductive load of resistance R in the plate circuit, an increase in the plate current of ∂I_p will cause a drop of plate voltage equal to $\partial I_p \cdot R$, which is equivalent to a drop μ times as small in the grid voltage. Hence the effective increase of grid voltage which must have caused the plate current to increase is less than the actual increase of grid voltage by this amount and ∂I_p is not equal to $S \cdot \partial V_g$ but

$$\partial I_p = S\left(\partial V_g - \frac{R}{\mu} \cdot \partial I_p\right) = \frac{\mu}{R_i}\partial V_g - \frac{R}{R_i}\partial I_p$$
$$= \frac{\mu \cdot \partial V_g}{R_i + R}.$$

If an alternating voltage with an effective value of v_g be applied to the grid, the effective value of the alternating current produced in the plate circuit is given by the equation *

$$i_p = \frac{\mu v_g}{R_i + R}.$$

The power supplied to the load is $i_p^2 R$ which reaches its maximum value when $R = R_i$, and is then

$$P_{max.} = \frac{\mu^2 v_g^2}{4R_i^2} \cdot R_i = \frac{\mu^2}{4R_i} \cdot v_g^2$$
$$\frac{4P_{max.}}{v_g^2} = \frac{\mu^2}{R_i} = S^2 R_i = S\mu.$$

This ratio of four times the maximum power output to the square of the input voltage has been taken by Barkhausen as a measure of the goodness of the tube; it might be called its figure of merit as an amplifier. Unfortunately it is not a mere numeral but has the dimensions of a conductivity; it differs therefore from an efficiency ratio in that it depends on the units adopted, but one cannot speak of the efficiency of an apparatus which gives a power output for zero power input, and there can be no input if the grid current is zero. The valve does not draw its supply of power from the grid but from the anode battery.

The figure of merit is proportional to the product of the steepness of the characteristic and the amplification factor. The former can be increased to some extent by decreasing the distance between the grid and filament, but a limit is soon reached in this direction; the amplification factor can be increased by making the openings in the grid very small. A high value of μ, however, gives a high internal resistance and therefore, to obtain the maximum output, a high load resistance; moreover, a close grid and a negative grid potential (to prevent grid current) necessitate a high plate voltage to bring the working point into the middle of the straight part of the characteristic. The high resistance and high plate voltage are disadvantageous from a practical point of view.

* The calculation of the amplification from the characteristics of the valve was described by Latour in his French Patent application of April 15th, 1916 (No. 512295).

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With the object of obtaining a large amplification factor without the disadvantage of a high voltage plate battery, valves with two grids were introduced (Fig. 1). If the voltage on the grid nearer the filament be called V_{g_1} and that on the other V_{g_2}, then

$$I_p = f[V_{g_1} + D_1(V_{g_2} + D_2 V_p)] = f[V_{g_1} + D_1 V_{g_2} + D_1 D_2 V_p]$$

or $$I_p = f\left[V_{g_1} + \frac{1}{\mu_1} V_{g_2} + \frac{1}{\mu_1 \mu_2} V_p\right].$$

So far as the filament and first grid are concerned the second grid and anode may be assumed to have an effective voltage $V_{g_2} + D_2 V_p = V_{g_2} + \frac{V_p}{\mu_2}$. This replaces the anode voltage of the ordinary valve. The filament, the first grid and this effective second grid may then be treated as an ordinary valve with an amplification factor μ_1, giving an effective voltage of $V_{g_1} + D_1(V_{g_2} + D_2 V_p)$ or $V_{g_1} + \frac{V_{g_2}}{\mu_1} + \frac{V_p}{\mu_1 \mu_2}$. The first grid G_1 is very open, the second G_2 very fine. The large openings in G_1 allow the anode voltage to be small; the small openings in G_2 cause a high amplification factor, which is now equal to the product $\mu_1 \mu_2$. The second grid being very positive and of fine mesh takes an appreciable current which is thus lost to the anode circuit.

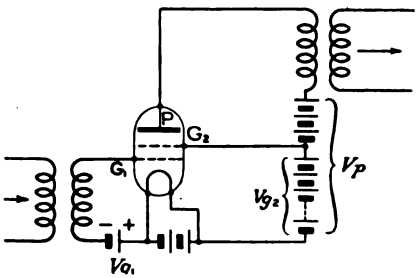

FIG. 1.

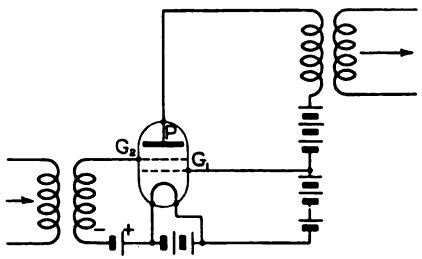

FIG. 2.

This must be minimised by making the anode sufficiently positive with respect to the grid. In an example given by Barkhausen μ_1 is $3\frac{1}{3}$, requiring a voltage V_{g_2} of about 20 to bring the working point on the steep part of the characteristic for $V_{g_1} = -1$ volt. μ_2 can then be made about 30 and the anode voltage V_p about 30, that is 10 volts higher than V_{g_2}. The resultant amplification ratio is then $30 \times 3\frac{1}{3} = 100$. To obtain this with a single-grid tube would require an anode voltage of about 600.

Fig. 2 shows another method of using valves with two grids. The slightly negative input circuit is here connected to the second grid, whilst the first grid is connected to the anode battery and thus raised to a potential equal to or nearly as high as that of the plate itself, which, however, is only about 10 volts. The emission current reaches nearly the saturation value, the

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electrons passing through the first grid and forming a space charge in the space between it and the anode. With respect to P and G_2 the first grid may be regarded as the source of the electrons. The space charge being so distributed, it is easily controlled by G_2, which results in a steep characteristic and an increased figure of merit.

In the method shown in Fig. 1, G_2 may be called an anode-screening grid, since its function is to screen the control grid G_1 and the filament from the effects of the fluctuations of the anode potential which normally limit the amplification. In the method shown in Fig. 2, G_1 may be called the space-charge grid or filament-screening grid since its function is to produce a re-distribution of the space charge on which G_2 acts. It is claimed that for a given anode voltage the figure of merit can be increased tenfold by the use of these double-grid valves. Barkhausen claims that the advantages of both the above methods could be combined in a valve with three grids, but any advantage thus gained would be counter-balanced by the constructional disadvantages.

On a Kink in the Characteristic of a Soft Three-electrode Valve.*

By B. HODGSON, O.B.E., M.Sc., Ph.D., and L. S. PALMER, M.Sc.

1. Introductory.—It has been known for some time that a three-electrode valve containing a trace of gas is much more sensitive as a detector for wireless signals than a geometrically similar hard valve. In the case of a soft valve there is usually a very critical adjustment at which the sensitiveness is abnormally great whilst with the hard valve no such point can be found. Such a sensitive valve was obtained by W. C. White † who introduced into the bulb a small quantity of mercury vapour. He proved that the characteristic possessed a discontinuity or "kink" at the particular adjustment for which it was most sensitive as a detector. The mercury vapour was introduced into the valve by using a silver amalgamated anode. Referring to this phenomenon, Dr. Eccles ‡ states in his handbook, "To ensure the necessary gas pressure there is placed in the bulb before sealing off a small amount of vapourisable material, for example, an amalgam, or sulphur or phosphorus pentoxide." Later he states that the cause of this phenomenon is decidedly obscure but its existence very real. The present work was undertaken to investigate the causes of the "kink."

2. Form of the Kink.—Typical forms of kinks are given in Figs. 1, 2 and 3 which were obtained by varying the grid potential v and observing the anode current I and the grid current i. Fig. 1 is the characteristic of a mercury vapour valve (the N.P.L. No. 2 valve), which contains an amalga-

* Received February 3rd, 1921.

† W. C. White, *General Electric Review*, p. 635, August, 1917.

‡ W. H. Eccles, "Handbook of Wireless Telegraphy and Telephony," pp. 295–296, 1918 edition.

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mated silver anode. Fig. 3 shows a kink from the same valve on a larger scale, and Fig. 2 shows a kink from a helium filled valve—the R.2A receiving valve. The kink obtained by White in the paper previously referred to is very similar in form to these. An important point, which will be referred to later, is that the changes in the grid and anode currents are similar and occur simultaneously.

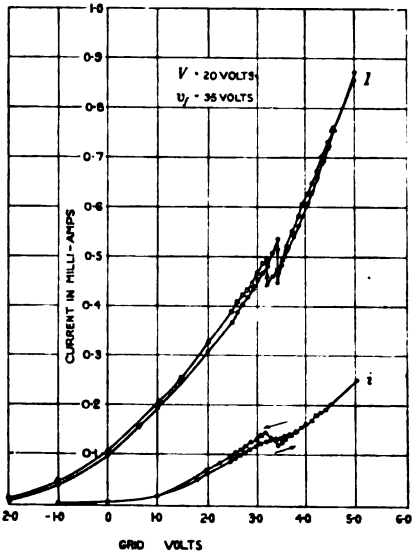

FIG. 1.—N.P.L. No. 2 (Hg) Valve.

3. Relation between Grid Potential, Anode Potential and Filament Temperature at the Point where a Kink occurs in the Characteristic.—A series of experiments were made in which the grid potential v, the plate potential V and the voltage across the filament v_f were measured at the point where the kink occurred. As is customary all potentials were measured from the negative end of the filament. The plate current I and grid current i were also recorded. It was noticed that with a dull filament [*i.e.*, v_f small] a relatively high value of plate potential was necessary to obtain a kink, and on the other hand, high values of v_f made it possible to obtain kinks with relatively low values of V. Fig. 4 shows the results of these experiments. The circles on the boundary curve shown indicate the lowest values of V for the corresponding filament voltage at which it was possible to get a kink. For example, with a filament voltage of 3·2 volts kinks can be obtained with any value of V greater than 14, by a suitable selection of v, but with V less than 14 no adjustment of the grid voltage would produce a kink. Thus the boundary curve shown divides the region determined by any values of V and v_f into

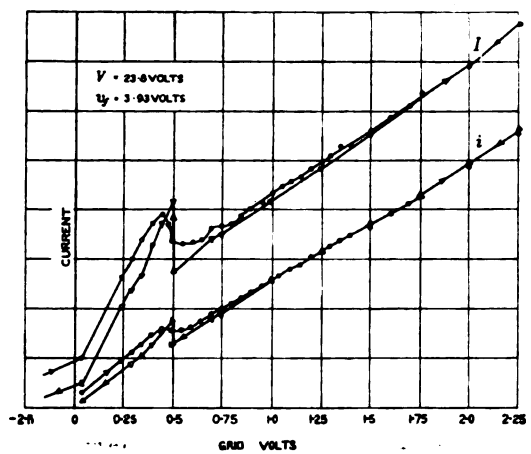

FIG. 2.—R.2A (He) Valve.
I and *i* are displaced vertically and not to same scale.

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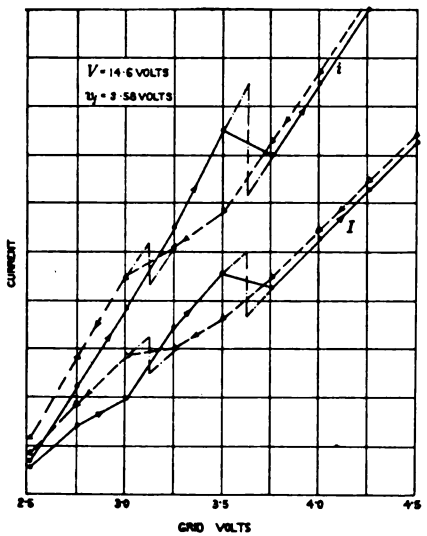

FIG. 3.—N.P.L. No. 2 (Hg) Valve. *I* and *i* are displaced vertically and are not to same scale.

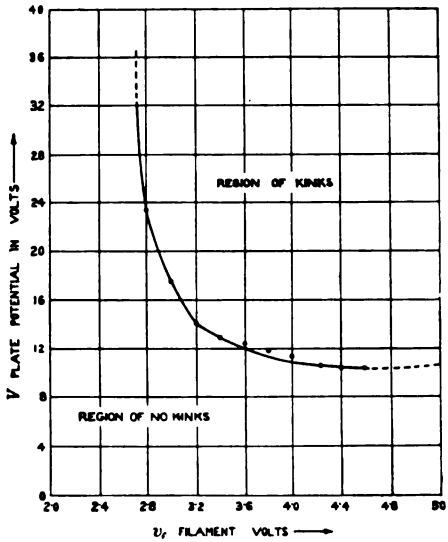

FIG. 4.—N.P.L. No. 2 (Hg) Valve.

two. At any point above the curve a suitable adjustment of v will produce a kink, the values of V and v_f being determined by the position of the point, but for any point below the boundary curve a kink can never be obtained.

Although a kink cannot be obtained with the conditions represented by a point below the boundary curve yet a deviation from the ordinary characteristic can be observed. Fig. 5 shows the characteristics obtained under conditions where V is just sufficient and also just insufficient to produce a kink, and the deviation from the normal characteristic is clearly noticeable. In Fig. 6 curves are shown where v_f is constant and V gradually increased until a kink is obtained.

The experiments performed suggested that some phenomenon essential to the production of a kink was occurring at the grid and an estimate of the energy of the electrons when they arrived in the neighbourhood of the grid was obtained. This energy depends upon the velocity of emission of the electrons from the tungsten filament and upon the potentials of both grid and anode. The velocity of emission is a function of the temperature of the filament which varies considerably from one end to the other. The majority of the electrons come from the mid-portion of the filament where it is hottest and where the velocity of emission is therefore greatest. In the following considerations the electrons are assumed to start from the mid-portion of the filament and thus to fall through a potential of $\left(v - \frac{v_f}{2}\right)$ in

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passing from the filament to the grid wire, and through a potential of $\left(V - \frac{v_f}{2}\right)$ in passing from the filament to the anode.

The surface containing the grid wires is usually a cylinder or a plane and is not an equipotential surface. The wires themselves are maintained by batteries at a potential v, but the potential of the space between the grid wires varies from point to point. The amount of variation depends upon the geometry of the valve and the potential of the anode V. Although the potential of any point in the surface containing the grid wires cannot readily be calculated, an average potential for the surface can be obtained easily by experiment. This average potential is usually written in the form $(v + \gamma V)$ where γ is a constant depending upon the geometrical distribution of the electrodes.

Then it has been shown that

$$I = A(v + \gamma V)^m$$

where A and m are constants.

By obtaining the same values of I with different combinations of v and V, γ can be calculated.

The expression $(v + \gamma V)$ yields an approximate value for the potential through which an electron falls in passing from the filament to the grid cylinder. Assuming that the electrons came from the mid-point of the

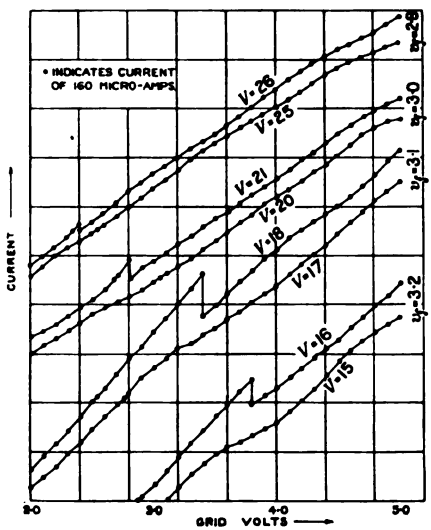

FIG. 5.—N.P.L. No. 2 (Hg) Valve.
Curves displaced vertically. Side of one square represents 33 micro-amps.

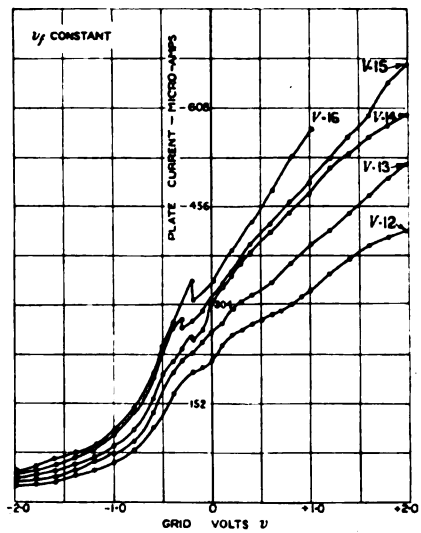

FIG. 6.

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filament, this expression becomes :—

$$\left(v - \frac{v_f}{2}\right) + \gamma\left(V - \frac{v_f}{2}\right).$$

Further, if the electron is ejected from the filament with the energy it would acquire in falling freely through the voltage e, then an electron in passing to the grid cylinder from the mid-point of the filament, possesses energy equal to that acquired in falling through a voltage—

$$\left(v - \frac{v_f}{2}\right) + \gamma\left(V - \frac{v_f}{2}\right) + e.$$

Similarly the energy possessed by an electron on arriving at the plate and coming from the mid-point of the filament is that acquired in falling through a potential of

$$\left(V - \frac{v_f}{2} + e\right).$$

The quantity e was determined by a method similar to that adopted by Van der Bijl. The anode was maintained at a constant potential which was less than the ionising potential of the gas and the grid was reduced in potential till the anode current was nearly zero. Then

$$-v = \gamma V + e.$$

By obtaining the same current with two different values of v and V, e and γ could be determined.

4. Experimental Results.—In addition to the helium-filled R.2A valve and the N.P.L. No. 2 mercury vapour valve, there were used an R valve filled with a pure argon and an audion. This latter is an air valve with a fairly good vacuum and the residual gas is chiefly nitrogen since any oxygen present would combine with the tungsten filament and be sputtered to the walls of the valve as oxide.

Kinks were obtained with all these valves for different values of V, v, and v_f, and the functions :—

$$\left[V - \frac{v_f}{2} + e\right] \text{ and } \left[v - \frac{v_f}{2} + \gamma\left(V - \frac{v_f}{2}\right) + e\right] \text{ calculated.}$$

These quantities will be denoted by V_a and V_g respectively. They were plotted against v_f, and V_a yielded a region of kinks and one of no kinks with a boundary curve very similar to that of Fig. 4. In Fig. 7 curves for the four gases are shown.

It will be seen that the boundary curves tend to become horizontal and possess minimum values of V_a for large values of v_f. These minimum values of V_a are roughly the ionising potentials of the gases. The minimum values of V_a thus determined and of the ionising potentials of the gases in question are shown in Table I. The column (I.P)* shows the ionizing potentials found by a method used by the authors with the actual valves employed in the present piece of work.

* Hodgson and Palmer, RADIO REVIEW, 1, pp. 525—531, August, 1920.

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TABLE I.

Gas.	V_a.	I.P.	Ionising Potentials.
Mercury . .	10·5	10·4	10·2 * 10·3 †
Helium . .	22·0	21·9	25·7 ‡ 25·3 § 25·5 ‖
Argon . .	16·6	16·6	15·1 and 18·1 ¶ 17 **
Nitrogen . .	18·0	17·4	18·5 †† 17·18 ‡‡

* *Physical Review*, 10, p. 495.
† *Physical Review*, 10, p. 101.
‡ *Proceedings of the Royal Society*, 95A, p. 408.
§ *Physikalische Zeitschrift*, 20, No. 21.
‖ RADIO REVIEW, 2, pp. 113—125, March, 1921.
¶ *Proceedings of the Royal Society*, 97A, p. 1.
** *Physical Review*, 13, p. 297.
†† *Physical Review*, 13, p. 1.
‡‡ *Physical Review*, 14, p. 409.

The minimum value of V_a is very approximately the ionising potential of the gas, and it appears essential to the production of a kink that this value of V_a should be reached.

When the values of V_g (the energy an electron possesses on arriving at the grid), were plotted against v_f, straight lines were obtained. The values of V_g are reasonably constant over the whole range of filament voltage used.

In the case of helium and mercury vapour two kinks upon one characteristic were obtained. The values of V_g found are given in Table II.

TABLE II.

Gas.	V_g	Resonance Potentials.
Helium . .	6·1 4·5	20·54 * 20·7 †
Mercury . .	6·3 4·7	6·7 ‡ 4·9
Nitrogen . .	7·3	7·3—8·3 §—9·0 ‖
Argon . .	11·4	12·0 ¶ 11·5 ** 12·5 ††

* *Proceedings of the Royal Society*, 95A, p. 408.
† RADIO REVIEW, 2, pp. 113—125, March, 1921.
‡ *Physical Review*, 10, p. 101.
§ *Physical Review*, 14, p. 409.
‖ *Physical Review*, 13, p. 1.
¶ *Physical Review*, 13, p. 297.
** *Proceedings of the Royal Society*, 97A, p. 1.
†† RADIO REVIEW, 2, pp. 113—125, March, 1921.

Except in the case of helium the values of V_g correspond to some known resonance potential of the gas in question, with helium resonance potentials as low as 4 or 6 volts have never been detected. The valves used for helium were factory made and further experiments are being undertaken to obtain

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V_a and V_g with pure helium. The fact that the ionising potential of the helium used was also less verifies the assumption that the helium was impure for Horton * found a steady decrease in the value of the ionising potential as the amount of impurity was increased. Table III., which gives some data for argon, illustrates two additional facts with regard to the values of V_a and V_g. The values of V_g are seen to be approximately constant over a range of pressures from 0·03 mm to 0·8 mm of mercury and the minimum value of V_a for a pressure of 0·03 mm was 16·57 and for a pressure of 0·8, 16·6 volts. By using a valve of different electrode geometry no change was found in the value of V_g and although the minimum value of V_a was not reached it was certainly not greater than 16·6 volts. The values of V_a and V_g thus appear to be independent of the electrode geometry and also of the gas pressure.

TABLE III.

Valve.	Pressure. (mm of Hg.)	V_a. (Volts.)	V_g. (Volts.)	Anode Current I. (Arbitrary units.)	γ.	v_f. Volts.)
R. valve filled with argon.	0·03	16·57	11·4	10·7	0·37	7·2
	0·03	19·4	11·4	10·5	0·35	7·0
	0·45	16·6	11·1	10·6	0·37	7·0
	0·55	16·6	10·4	10·5	0·40	7·0
	0·80	16·6	10·3	10·4	0·40	7·0
Another argon-filled valve.	—	22·2	10·2	—	0·16	3·4
	—	21·9	12·4	—	0·16	3·2
		(16·57) Min. value	(11·0) Mean value			

Another experimental fact recorded in Table III. is that the value the anode current I assumes when a kink occurs, is practically constant for a particular valve, but probably this is dependent upon the fact that V_g is constant, because

$$V_g = v - \frac{v_f}{2} + \gamma\left(V - \frac{v_f}{2}\right) + e = v + \gamma V + \left[e - (1+\gamma)\frac{v_f}{2}\right]$$

and $\left[e - (1+\gamma)\frac{v_f}{2}\right]$ is seen from the following table to be approximately constant.

* Horton, *Physical Review*, 15, p. 498, and Palmer, RADIO REVIEW, 2, pp. 113—125, March, 1921.

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TABLE IV.

v_f	$[e - (1 + \gamma)v_f/2.]$			$[e - (1 + \gamma)v_f/4.]$
	N.P.L. No. 2. (Mercury.)	R.2A. (Helium.)	R. (Argon.)	Audion. (Nitrogen.)
2·5	0·05	— 0·5		
3·0	0·20	— 0·3		
3·5	0·10	— 0·2	—	3·2
4·0	0·05	— 0·2	—	3·1
4·5	0·10	— 0·4	—	3·1
5·0	0·40 *	— 0·5	— 1·4	3·0
6·8	—	—	— 1·4	
7·0	—	—	— 2·0 *	
7·2				

Thus $(v + \gamma V)$ is roughly constant and this is the condition that I does not vary. The experimental values of I at which kinks occurred are shown in Fig. 8 and it will be seen that I is approximately constant for all values of

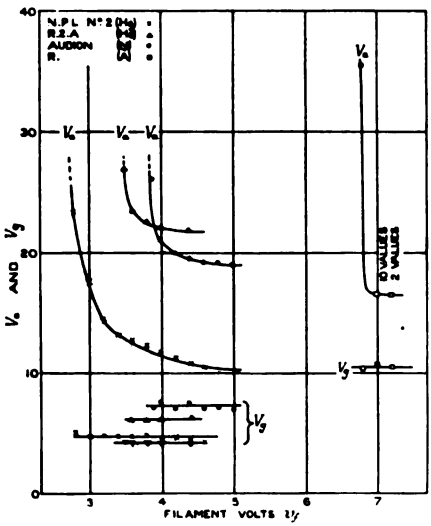

FIG. 7.

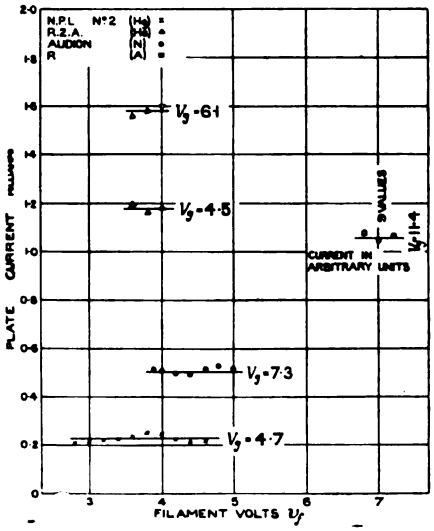

FIG. 8.

* Filament very thin and very hot.

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v_f for a given valve. It was noted in section **2** and in Figs. 2 and 3 that the current changes for both plate and grid currents were similar in form and that the changes occurred simultaneously. This fact is of importance when an explanation of the phenomena is sought as certain possible causes are thus eliminated.

Another experimental fact is the small difference in position of the kink when obtained first with increasing and secondly with decreasing grid potential. This "lag" is seen in Figs. 1, 2, 3, 12, and 13.

5. Discussion.—There is little doubt that ionisation is an essential part of the kink phenomena, because a kink has not been observed in a hard valve, and in a soft valve only under conditions where ionisation is possible. The evidence that a resonance potential occurs near the grid is not so strong. It depends upon the observed fact that the values of V_g in the gases argon, nitrogen and mercury are very near the respective resonance potentials of these gases.

If one assumes that the origin of the kink is in physical processes occurring in the valve itself, then the following analysis of the currents I and i shows that the source of the current carriers producing the changes in I and i

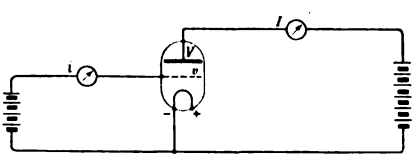

FIG. 9.

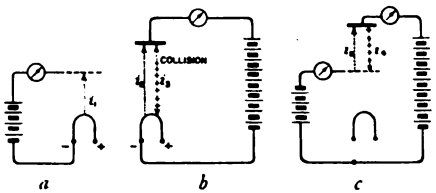

FIG. 10.

must be the filament. The circuit used in obtaining the characteristics can be shown diagrammatically as in Fig. 9.

In the valve there are three possible paths for the current carriers, viz. :—

(1) From filament to plate and *vice versâ*.
(2) From filament to grid and *vice versâ*.
(3) From grid to plate and *vice versâ*.

Thus we may consider the circuit of Fig. 9 to consist of three component circuits as shown in Fig. 10.

The electrons and positive ions carrying the currents in these circuits are due to various causes. The hot filament yields the bulk of the electrons. The positive ions are formed by collision between electrons and gas molecules, and as the grid potential v under the conditions that yield a kink, is much less than ionising potential and the plate potential V is above it, the positive ions are formed in the space between the grid and the plate. Photo-electrons can be emitted from the metal electrodes if ultra-violet light of suitable wavelength is generated in the tube. This occurs when an electron collides with a gas molecule after falling through "Resonance" potential. For example, an electron that has gained energy in falling through a potential of 4·9 volts and collides with a mercury vapour molecule, causes ultra-

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violet light of a single wavelength to be emitted from the bombarded molecule. No ionisation occurs until the electron has fallen through 10·4 volts.

Now mercury vapour has three resonance potentials at 3·2, 4·9 and 6·7 volts respectively, and with the mercury vapour valve two kinks were often obtained, with values of V_g 4·7 and 6·3 volts. When ultra-violet light falls upon metals, electrons are only emitted if the wavelength of the light is below a certain threshold value which depends upon the metal upon which the light is incident. In the case of a molybdenum grid the wavelength corresponding to 3·2 volts resonance potential is above this threshold value, and a kink with a 3·2 volt value for V_g would not be expected.

The bombardment of the filament by positive ions is a further cause of electron emission. Intense local heating is produced where the ion strikes the filament and increased emission results.

The bombardment of the grid and plate by both electrons and positive ions can produce additional carriers of current,* but these will be few in number under the conditions of the experiments with which we are concerned.

The plate current I is the sum of the plate currents in circuits b and c of Fig. 10, viz.:—

i_2 an electron current from filament to plate (circuit b).
i_3 a positive ion current from plate to filament (circuit b).
i_4 a positive ion current from plate to grid (circuit c).
i_5 a photo-electron current from grid to plate (circuit c).

Thus $I = i_2 + i_3 + i_4 + i_5$.

The grid current i consists of the sum of the grid currents in circuits a and c, viz.:—

i_1 an electron current from filament to grid (circuit a).
i_5 a photo-electron current from grid to plate (circuit c).
i_4 a positive ion current from plate to grid (circuit c).

Thus $i = i_1 - i_4 - i_5$.

This analysis of the currents I and i, together with the fact that both I and i increase or decrease simultaneously, enables one to eliminate certain phenomena as causes of the kink. For example a photo-electric current from the grid alone cannot be the cause, for this would mean an increase in I when the effect sets in, and a decrease in i by the same amount i_5.

Similarly ionisation alone demands an increase in I accompanied by a decrease in i by the amount i_4. This is readily observed in a soft valve and an example of this is shown in Figs. 11 and 11A. The "backlash" test for the vacuum of a three-electrode valve also utilises this fact. If however any of these phenomena are accompanied by a bombardment of the filament by positive ions, the extra electron emission might mask the decrease in the value of i and produce a simultaneous increase in I and i.

A satisfactory explanation of the kink based upon the experimental evidence given above is, however, difficult to find. If photo-electrons from the grid wires produced additional ionisation, then a discontinuity in the characteristic would be expected. The photo-electrons falling from grid to

* Horton, *Proceedings of the Royal Society*, 95A, p. 419.

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anode do not always possess energy sufficient to ionise—as for example when V_a has its minimum value—in which case the potential fall between grid wires and anode is usually much less than ionising potential. Thus ionisation by photo-electrons is not possible and the simultaneous rise in both grid and plate current cannot be thus explained.

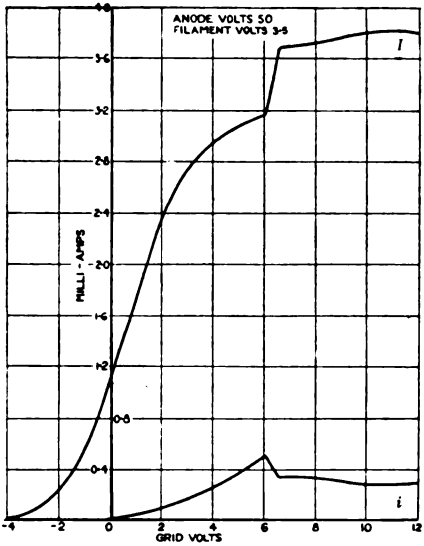

FIG. 11.

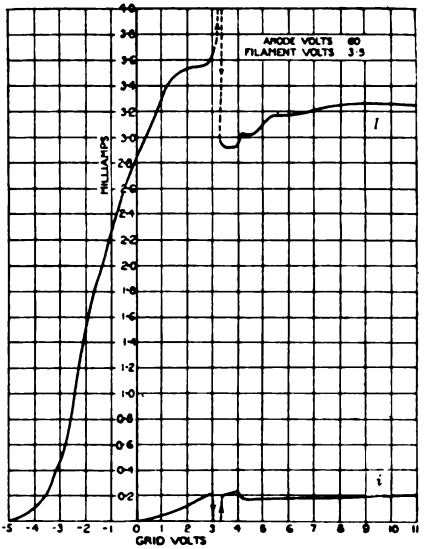

FIG. 11A.

Nor can the space charge effect due to photo-electrons emitted from the grid yield a satisfactory explanation. The region in which resonance collision occurs moves from near the anode towards the grid, as the grid potential is increased and radiation from this region falls in increasing amount upon the grid wires. Photo-electrons will be projected from the grid wires towards the anode, and they will be removed rapidly from the grid. When, however, the region on which resonance occurs appears between the grid and the filament, the photo-electrons are projected from the filament side of the grid wires into a field which tends to drive them back to the grid, and their presence here will tend to diminish the electron emission from the filament —by diminishing the field at the surface of the filament. It is improbable however that the photo-electrons are in sufficient number to produce the kink by such action as described.

Another possible explanation is afforded by the similarity of the changes in I and i with those observed when a valve generates an oscillatory current. Whiddington * has shown that high frequency oscillation can be generated in circuits devoid of the usual inductance-capacity arrangements. In the case described by him, the oscillations are maintained by the periodic bombardment of the filament by positive ions produced by the collision of

* RADIO REVIEW, 1, p. 53, November, 1919.

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the electrons with gas molecules. When a valve commences to generate oscillations both I and i usually increase, and if the oscillations for some reason ceased then the current I would fall back to the corresponding point upon the characteristic. Further, if oscillations are started by changing the grid potential, the point where the sudden change in anode current occurred would depend upon whether the grid potential was increasing or decreasing. Thus the generation of oscillations would account for all the observed phenomena of the kink. Whiddington assumed that a cloud of electrons from the filament collided with gas molecules just outside the grid and ionised them. The resulting positive ions were driven as a group back to the filament and the local heating of the filament by this bombardment produced another cloud of electrons. In this way both the I and i currents would be periodically increased, and this periodic fluctuation of these currents could be detected in a beat reception circuit placed near, and the periodicity or wavelength of the oscillatory current measured. The periodicity can also be calculated by finding the times between two consecutive bombardments.

The energy equation

$$\tfrac{1}{2}mu^2 = \overline{V} \cdot e$$

(where m is the moving mass, u its final velocity, $\overline{V}$ the potential through which m falls, and e its charge), yields the final velocity u. The time between two bombardments is the time taken for the electrons to reach the molecules with which they collide, plus the time taken for the positive ions so produced to fall to the filament. As the former time is small compared to the latter, only the latter need be evaluated. Whiddington took the quantity $\overline{V}$ as the potential between the filament and the grid, and the following quantities are those used by him to evaluate the frequency of the oscillations generated by the valve.

$\overline{V} = 1$ volt.

$e/m = 50$ (E.M.U.) (for mercury atoms).

Hence $u = 10^5$ cm/sec.

The distance between filament and grid was 3 mm.

Thus the mean time between two collisions was $6{\cdot}0 \times 10^{-6}$ secs.

This yields a frequency of $\frac{1}{6} \times 10^6$ or a wavelength of 1,800 metres and not as Whiddington works out, 450 metres. Since he found experimentally a wavelength of 640 metres, there is no agreement between experiment and theory. His theory can, however, be amended readily to give a reasonable agreement. Suppose that the electrons are emitted from the filament with zero velocity, then they must fall through a field of about 10·4 volts in order to acquire ionising velocity in mercury vapour, and they will acquire this energy just outside the grid because the plate voltage used was 50 volts or more. Thus the final velocity will be:—

$$\sqrt{10{\cdot}4} \times 10^5 \text{ cm/sec} = 3{\cdot}16 \times 10^5 \text{ cm/sec}$$

and the mean velocity $1{\cdot}58 \times 10^5$ cm/sec

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and the mean time between two bombardments will be $1{\cdot}9 \times 10^6$ secs and the corresponding wavelength 570 metres.

This, however, is only a lower limit of the value of the frequency because the electrons are emitted with some initial velocity. This reduces the value of the field through which they must fall to acquire ionising velocity and so increases the wavelength of the generated oscillatory current.

Thus in such a valve as Whiddington used, wavelengths of 570 metres upwards should be generated if this modified theory is correct. This is in fair agreement with the 640 metres found by Whiddington.

It was thought that oscillations of this sort might be generated when a kink occurred. In the experiments performed to yield a kink, ionisation occurred somewhere between the grid and the anode, and the distance the positive ions travel before reaching the filament is not known exactly but is between two limits D and d, where D is the distance between the filament and the anode, and d the distance between filament and grid. Using these two distances and the theory outlined above, two frequencies were calculated between which the frequency should be observed if oscillations occur during a kink. The following table gives the data concerning three of the valves in use and the expected frequencies.

TABLE V.

Gas.	d.	D.	e/m.	$\bar{V}$.	u (final).	λ_1.	λ_2.
Mercury	0·14	0·44	48	10·4	$3{\cdot}16 \times 10^5$	268 m	840 m
Nitrogen	0·22	0·49	340	17·5	$1{\cdot}1 \times 10^6$	120 m	267 m
Argon .	0·17	0·45	240	16·6	$8{\cdot}9 \times 10^5$	114 m	300 m

Where λ_1 and λ_2 are the lower and upper limits of wavelength and $\bar{V}$ the ionising potential in volts.

A search for such frequencies between wavelengths of 100 and 2,000 metres was made, but no oscillations could be detected. A more sensitive receiver is being made to make a further search.

The addition of inductances to either the grid or anode branches of the circuit used for obtaining the kink produced no change in its size or position. Inductances from a few hundred centimetres to a value of 43 million centimetres were used.

The effect of connecting either anode to filament or grid to filament by means of condensers also produced no effect. When non-inductive resistances (platinum films on glass) up to 80,000 ohms were inserted in either the grid or anode circuits, no change in the kink was obtained, provided that the anode battery was adjusted so that the potential difference between filament and anode was the same. Figs. 12 and 13 show the forms of the I kink with and without inductances, capacities and resistances.

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The above experiments show that if the kink phenomena are produced by the generation of oscillations then such oscillations are practically independent of the nature of the grid and anode circuits.

In soft vacuum tubes sudden changes in current similar to that observed in the kink are common—especially when there is connected to the bulb through which the visible discharge usually passes, a tube leading to other volumes of gas. Under certain conditions the glow extends beyond the bulb into the connecting tube and an increase in current can be observed. A similar phenomenon might occur in the valve. The main discharge usually occurs in a very limited volume of the bulb—that between the filament and anode—but it is quite possible that gas in the remaining portion of the bulb takes part in conducting the current under certain electrical potentials of grid and plate.

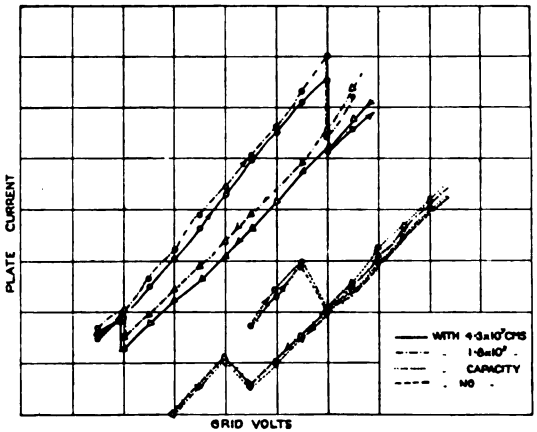

FIG. 12.

The experiments described have not solved the problem of the kink, but it is hoped that the additional knowledge concerning the kink phenomena may lead to an early solution.

The advantages of the remarkable rectifying power of the valve, when adjusted for a "kink," can now be more readily used, because the essential conditions can be very approximately calculated.

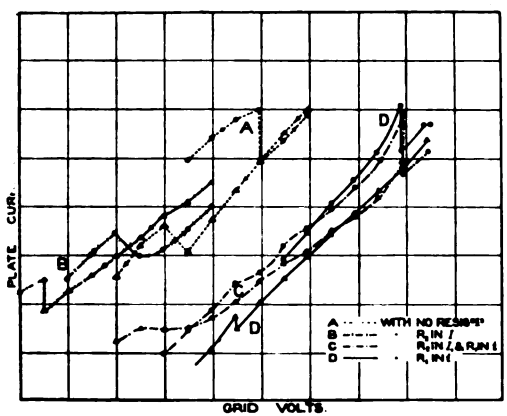

FIG. 13.

6. Summary.—(1) The kink in the characteristic of a soft three-electrode valve has been obtained in five types of valves and with four different gases.

(2) The necessary conditions for obtaining a kink are:—

(*a*) The valve should be "soft."

(*b*) The function V_a must be at least the ionising potential of the gas in the tube.

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(*c*) The function V_g must be a resonance potential of the gas in the tube.

(*d*) The resonance potential must exceed in value the minimum potential necessary for the emission of photo-electrons from the material of the grid.

(3) The kink is independent of :—

(*a*) The gas pressure.

(*b*) The valve geometry.

(*c*) The nature of the external circuit.

(4) Possible explanations have been discussed, but a satisfactory solution has not yet been found.

The above work was carried out in the Physics Department of the University of Bristol, and the expenses entailed were met by a grant from the University Colston Research Fund.

A New Dutch Marine Type Receiver.

The standard receiving apparatus manufactured by the Nederlandsche Radio Industrie is arranged for the reception of all European and the principal trans-ocean radio stations, and is suitable for both telephonic and telegraphic reception on wavelengths between 400 and 20,000 metres. It consists of

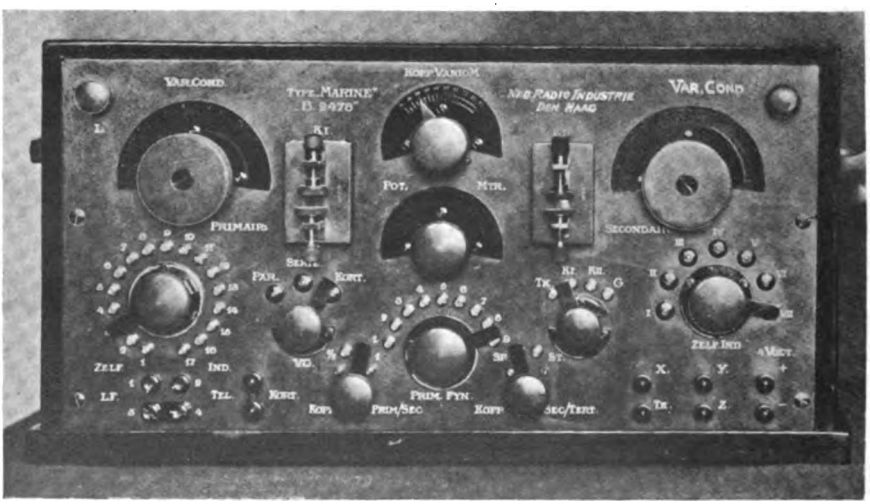

FIG. 1.

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two parts : the Receiver type " Marine B," and the Amplifier type " H.F. 1," Figs. 1 and 2. Both units are mounted in polished mahogany cases with ebonite front panels, on which are fitted all the terminals, adjusting and tuning handles and switches.

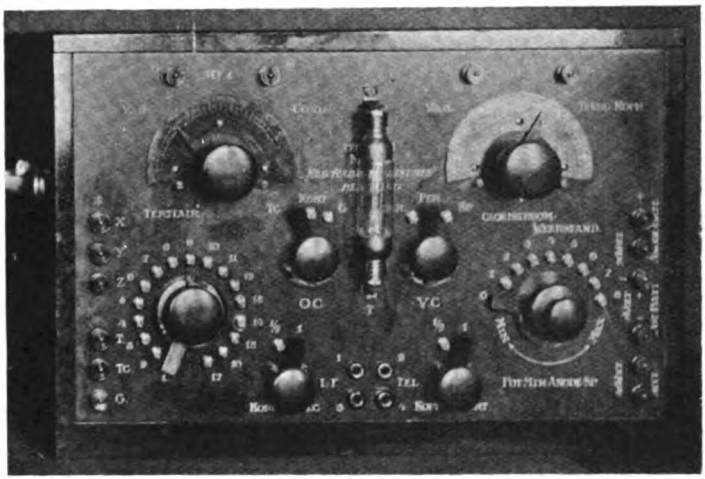

FIG. 2.

The arrangement of the receiver unit proper, type " Marine B," is shown in Fig. 3. It has inductive coupling between the aerial circuit and the secondary, the coupling coils being arranged like a variometer, with the inner coil connected in the aerial circuit. The advantages of this arrange-

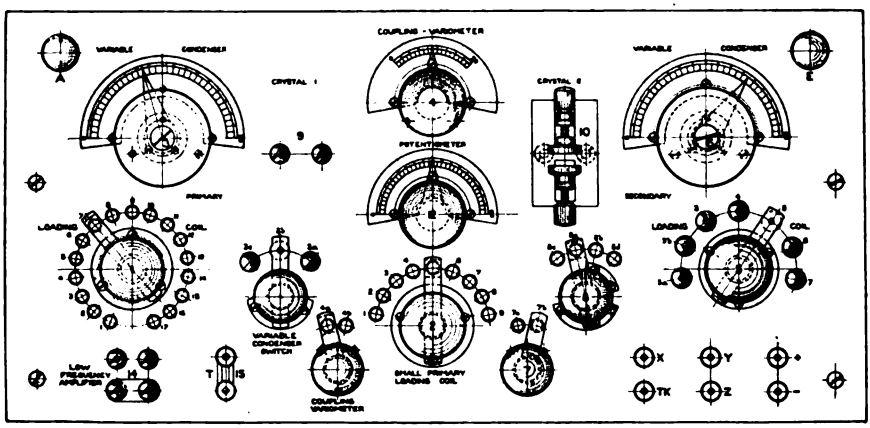

FIG. 3.

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ment are fineness of adjustment of the coupling and ability to reduce it completely to zero—an adjustment not easily possible with solenoid type coils. For short wave reception both coils of the coupling transformer are divided—the primary by a centre tapping, and the secondary into two parts which may be used singly or in series. With a normal aerial the coupling need not be greater than 20°—30°, except for wavelengths over 10,000 metres.

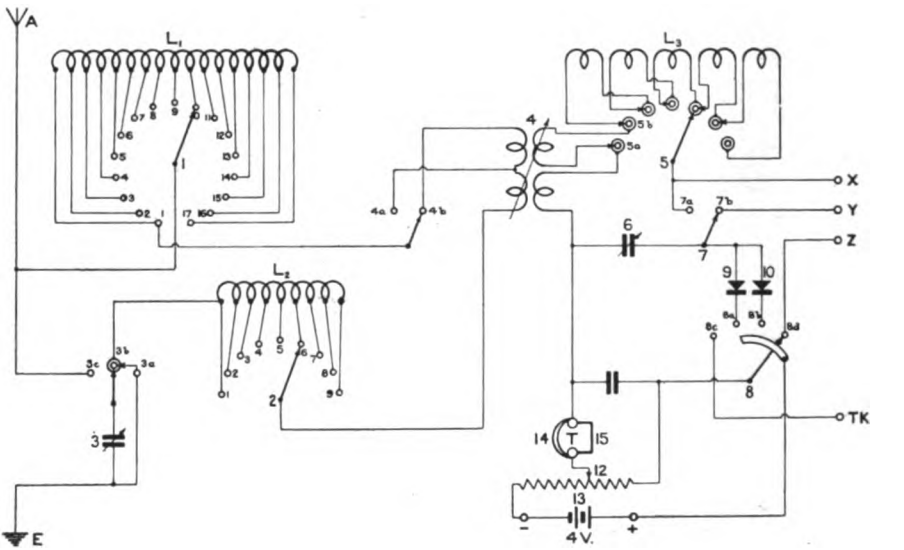

FIG. 4.

The rough tuning of the aerial circuit is accomplished by switch **1** (contacts 1—17) Figs. 3 and 4, and the fine tuning on switch **2** (contacts 1—9), the inductance of this second coil L_2 covering the range of inductance between two contacts of **1** on the coil L_1. Finer adjustment is obtained by the variable condenser **3** which may be placed in series, or in parallel with the aerial circuit or cut out entirely by the switch **3a**, **3b**, **3c**.

For aerials having a capacity greater than 0·005μF, it is suggested that the primary condenser **3** should be filled with paraffin oil.

The secondary circuit comprises the inductance L_3 with its tapping switch **5**, in parallel with the variable condenser **6**. The self-capacity of the coils is kept down as much as practicable, and the minimum capacity of condenser **6** is also small (about 0·00003μF). The tapping switch **5** is fitted with dead-end contacts to cut off the parts of the winding which are not in use.

When this receiver unit is used alone, for crystal reception, switch **7** is put on contact **7a**, and switch **8** enables either of the crystal detectors **9** or **10** to be used, or a tikker to be connected to the terminals marked **TK** and **X**.

The two crystal detectors are mounted on the front of the panel by means

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of plug and socket connections. Either one or two pairs of telephones may be plugged into the contacts provided.

When valve reception is required the amplifier unit, type H.F. 1 is joined up by connecting the terminals marked **X Y Z** on the receiver unit to those

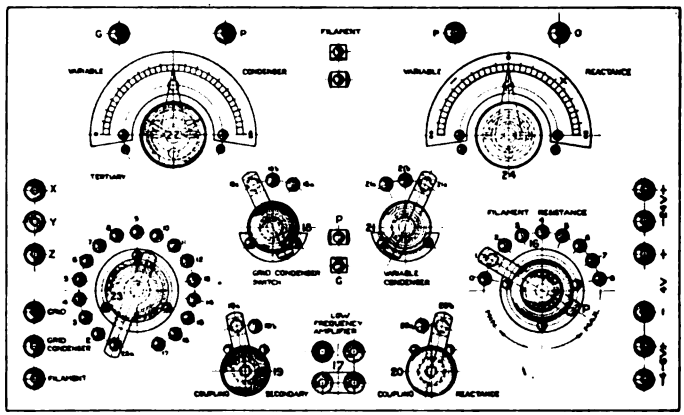

FIG. 5.

with the corresponding markings on the amplifier unit. The general arrangement of the front panel of this instrument is shown in Fig. 5, and the connection scheme in Fig. 6. To connect in this unit switch **8** is put on to contact **8d** which closes the connection between the tuned secondary circuit of the receiver unit and the tertiary circuit coupling coil of the amplifier unit.

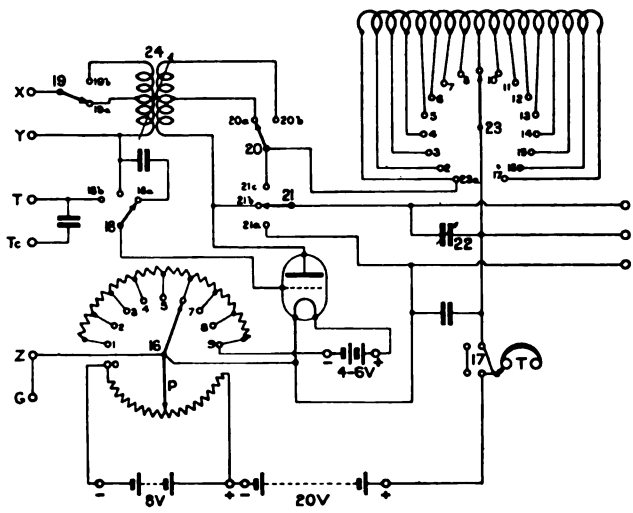

FIG. 6.

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The valve filament may then be regulated by the rheostat **16** and the telephones changed over from the sockets on the receiver unit to those marked **17** on the amplifier unit. This unit enables C.W. signals to be received. The condenser can be placed in the grid circuit by putting switch **18** on to contact **18a** or a negative potential can be applied to the grid if it is put on to contact **18b**. The value of this negative potential can be adjusted by means of potentiometer **12** on the receiver unit if the short-circuiting link **15** is put in place. A fine adjustment of the potential applied to the anode of the valve is obtained by means of the potentiometer P connected across eight volts of the unit battery. Reaction between the anode and grid circuits of the valve is obtained by means of the coupling **24**, both windings of which are tapped at the centre point so that either half or the whole of the coils may be obtained by means of the switches **19** and **20**. A variable condenser **22** can also be shunted across the reactance inductance to provide finer tuning. It is claimed that a more selective adjustment may be obtained when jamming is severe and when using the valve for detection, by placing switch **7** on the receiver unit over to the left-hand contact **7a** instead of to the right-hand contact **7b** as is usual when using the additional amplifier unit H.F. 1. When this change is made the reactance **23 24** needs a finer adjustment.

Current Suppression by Means of Parallel Resonance.*

By H. G. CORDES, Radio Research Engineer.

The theory of suppressing radio frequency current by means of parallel resonance has been little dealt with in radio publications. It is the purpose of this paper to present the theory of this subject as applicable to radio signalling. Parallel resonance includes all coupled circuits in which the secondary is adjusted for resonance to the E.M.F. impressed upon the primary but the term is generally applied to coupled circuits in which no useful energy is withdrawn from the secondary circuit, the function of the secondary circuit being the suppression of current in the primary having an undesired frequency. The term "parallel resonance" will be used to indicate resonance in a secondary circuit the function of which is to suppress an undesired frequency in the primary circuit.

The fact that a radio parallel resonance circuit is practically always associated with a series resonance circuit distinguishes the former from parallel resonance in power circuits. The large impedance of a parallel resonance circuit to the flow of current in the primary circuit is due to the reaction of stored energy and not to the reaction of storing energy, in other words, energy must be stored in the parallel resonance circuit before it im-

* Received in final form January 3rd, 1921.

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presses a counter E.M.F. upon the primary. This is similar to the counter E.M.F. of a motor with no load. The motor constitutes a large impedance to a steady impressed E.M.F. A change of impressed E.M.F. requires that kinetic energy be added to, or withdrawn from, the rotor which produces a flow of current. The energy stored varies with the size of the rotor; the energy stored in a parallel resonance circuit varies with the ratio of capacitance to inductance; and, the impedance decreases as the size or ratio increases.

The full benefits of parallel resonance are obtained when the current to be suppressed is a constant frequency sinoidal wave current having a constant or slowly varying amplitude. In addition to suppressing an undesired frequency parallel resonance can also be used to increase the selectivity of a received signal by suppressing the desired frequency in a circuit which is in parallel with a receiver.

In radio signalling where series resonance is desired at one frequency and parallel resonance at another frequency it is important to determine the condition which will simultaneously give minimum impedance to current of one frequency and maximum impedance to current of the other frequency. It is also desirable to introduce a parallel resonance circuit into a series resonance circuit without changing the resonant frequency of the series resonance circuit. The amplitudes of current and potential depend upon the impedance. The impedance depends upon the resistance and the reactance. The reactance depends upon the frequency. When the reactance is zero at a given frequency the resistance determines the amplitude of current and potential. In practice the reactance cannot be made zero, but it can be made small compared to the resistance of the circuit. The resistance of radio circuits is small compared to reactance at all frequencies except the resonant frequency at which frequency the reactance is small compared to the resistance. Adjustment depends upon reactance while efficiency depends upon resistance.

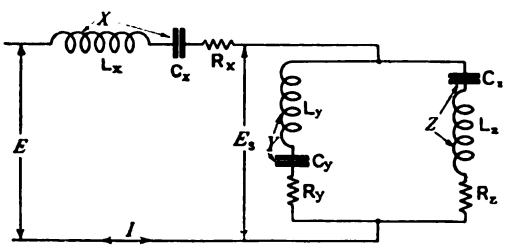

FIG. 1.

A parallel resonance circuit being a coupled circuit any type of coupling may be used to suppress current. The direct coupled circuit is best adapted to the suppression of current and will be the only one considered. All other types of coupling can be replaced with an equivalent direct coupling.

Fig. 1 shows a simple radio circuit. The inductance L_x and capacitance C_x having a resistance R_x constitute the series reactance of the series resonance circuit. The parallel reactances Y and Z constitute the parallel resonance

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circuit. The reactance Y is due to the inductance L_y, and capacitance C_y having resistance R_y and reactance Z is due to the inductance L_z and capacitance C_z having resistance R_z.

Let I = the effective current flowing in the series resonance circuit due to an effective potential E impressed upon the circuit.

Let I_1 = the effective current through L_y and C_y and let I_2 = the effective current through L_z and C_z. Then

$$I = I_1 + I_2 \text{ (vectorially)} \quad \ldots\ldots\ldots \quad (1)$$

The potential E_s in vector notation is

$$E_s = I_1(R_y - jY) = I_2(R_z - jZ) \quad \ldots\ldots\ldots \quad (2)$$

The potential E is

$$E = I(R_x - jX) + E_s \quad \ldots\ldots\ldots \quad (3)$$

Let $S = R_p - jP$ = the impedance of the parallel reactances. The impedance S will be referred to as "suppressive" impedance and the components, R_p as suppressive resistance, and P as suppressive reactance. Then from (1) and (2)

$$S = \frac{E_s}{I} = \frac{(R_y - jY)(R_z - jZ)}{R_y - jY + R_z - jZ} \quad \ldots\ldots \quad (4)$$

From (4) the suppressive resistance R_p is

$$R_p = \frac{(Y + Z)(R_zY + R_yZ) + (R_y + R_z)(R_yR_z - YZ)}{(R_y + R_z)^2 + (Y + Z)^2} \quad \ldots \quad (5)$$

and the suppressive reactance P is

$$P = \frac{(Y + Z)(R_yR_z - YZ) - (R_y + R_z)(R_zY + R_yZ)}{(R_y + R_z)^2 + (Y + Z)^2} \quad \ldots \quad (6)$$

Let $Q = R_u - jU$ = the total impedance of the parallel resonance circuit in series with the series resonance circuit, then

$$Q = \frac{E}{I} = R_x + R_p - j(X + P) \quad \ldots\ldots\ldots \quad (7)$$

From (7) $$R_u = R_x + R_p \quad \ldots\ldots\ldots\ldots\ldots \quad (8)$$

and $$U = X + P \quad \ldots\ldots\ldots\ldots\ldots \quad (9)$$

The scalar value of Q in the general equation (7) is

$$Q = \sqrt{\frac{[R_x(R_y + R_z) + R_yR_z - X(Y + Z) - ZY]^2 + [R_y(X + Z) + R_z(X + Y) + R_x(Z + Y)]^2}{(R_y + R_z)^2 + (Z + Y)^2}} \quad (10)$$

Equations (1) to (10) are general expressions from which special relations will be derived by letting certain reactances equal zero. The condition for series resonance is that $X + P = 0$ and for parallel resonance is that $Y + Z = 0$. For brevity let "suppressor" indicate the positive and negative reactances in parallel which constitute the suppressive impedance. The parallel resonance circuit will be referred to as the suppressor circuit.

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SERIES AND PARALLEL RESONANCE WITH ZERO PARALLEL REACTANCE.

It is desirable to obtain minimum impedance (series resonance) at one frequency and then secure maximum impedance (parallel resonance) at another frequency without annulling the adjustment for minimum impedance. This can be done by making both X and Y zero at the desired frequency and then making $Y + Z = 0$ at the undesired frequency by varying Z.

Let $Y = 0$ for the desired frequency, then from (5) the effective resistance of a zero-reactance suppressor is

$$R_p = \frac{R_y[Z^2 + R_z(R_y + R_z)]}{(R_y + R_z)^2 + Z^2} \quad \ldots\ldots\ldots (11)$$

and from (6)

$$P = -\frac{R_y^2 Z}{(R_y + R_z)^2 + Z^2} \quad \ldots\ldots\ldots (12)$$

Reactance Z is large compared to resistance R_y when the desired and undesired frequencies differ appreciably, therefore

$$\left.\begin{aligned} R_{p(\text{min.})} &= R_y \\ P_{(\text{min.})} &= 0 \\ S_{(\text{min.})} &= R_y \\ Q_{(\text{min.})} &= R_x + R_y \end{aligned}\right\} \quad \ldots\ldots\ldots (13)$$

Equations (13) are sufficiently accurate for practical purposes and show that series resonance or minimum reactance is practically independent of the value of Z. The value of Z may be either positive (inductance), negative (capacitance) or both (Fig. 1).

Let $Y + Z = 0$ for the undesired frequency, then from (5) the suppressive resistance is

$$R_{p(\text{max.})} = \frac{R_y R_z + Z^2}{R_y + R_z} = \frac{R_y R_z + Y^2}{R_y + R_z} \quad \ldots\ldots\ldots (14)$$

and the suppressive reactance is

$$P_{(\text{max.})} = \frac{(R_y - R_z)Z}{R_y + R_z} = \frac{(R_y - R_z)Y}{R_y + R_z} \quad \ldots\ldots\ldots (15)$$

Since Z is large compared to the resistances, equation (14), for practical purposes, becomes

$$R_{p(\text{max})} = \frac{Z^2}{R_y + R_z} = \frac{Y^2}{R_y + R_z} \quad \ldots\ldots\ldots (16)$$

Equation (15) shows that the suppressive reactance is zero when $R_y = R_z$ and approaches Z as either R_y or R_z becomes negligible compared to R_z or R_y. It is a common fallacy to refer to the reactance P as being infinite; the fact is that P is small or equals zero while R_p approaches infinity as the sum $R_y + R_z$ approaches zero. The value of R_p increases as the ratio of inductance to capacitance of the suppressor increases and also as the ratio of reactance to ohmic resistance increases.

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ZERO PARALLEL REACTANCE.

The method of adjusting the parallel reactance Y to zero at the frequency at which the series reactance X is zero will now be considered. Let ω, L and C represent frequency in radians, inductance and capacitance respectively. Then referring to Fig. 1, the relation $X = Y = 0$ when $\omega = \omega_1$ gives

$$\omega_1 L_x - \frac{1}{\omega_1 C_x} = \omega_1 L_y - \frac{1}{\omega_1 C_y} = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

From (17) $$L_y C_y = L_x C_x \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

which is the relation of inductances and capacitances of the series reactance X and a parallel reactance Y for zero value of U in equation (9).

There is a second frequency ω_2 at which $U = 0$. Resistances can be neglected in the determination of frequency. Neglecting resistances, (9) becomes

$$U = X + \frac{YZ}{Y + Z} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

From (18) substituted in (19)

$$U = (\omega^2 L_x C_x - 1)\left[\frac{1}{C_x} + \frac{\omega^2 L_z C_z - 1}{\omega^2 L_x C_x + \omega^2 L_z C_z C_y - (C_y + C_z)}\right] \quad . \quad . \quad (20)$$

From (20) $U = 0$ when

$$\omega_1^2 = \frac{1}{L_x C_x} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

and when $$\omega_2^2 = \frac{C_x + C_y + C_z}{[L_x C_x + L_z(C_x + C_y)]C_z} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

The frequency ω_1 is independent of the values of L_z and C_z. The second resonant frequency ω_2 can seldom be utilised in radio circuits.

Maximum impedance is determined by zero reactance in the suppressor circuit. Let $\omega = \omega_\infty$ when $Y + Z = 0$ in (19). Then

$$\omega_\infty^2 = \frac{C_y + C_z}{C_y C_z (L_y + L_z)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

The frequency ω_∞ is independent of the values of L_x and C_x. There is only one frequency at which the impedance is a maximum. When ω_∞ is known equation (23) can be solved for C_z or L_z to find the value required to suppress a given ω_∞.

AMPLITUDE OF CURRENTS AND POTENTIALS.

When resistances are negligible compared to reactances and P is negligible compared to X the minimum value of I from (7) and (16) is

$$I_{(\text{min.})} = \frac{E}{\sqrt{\left(\frac{Y^2}{R_y + R_z}\right)^2 + X^2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (24)$$

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The maximum value of I from (7) and (13) is

$$I_{(max.)} = \frac{E}{R_x + R_y} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

Assume that $I_{(min.)}$ is negligible compared with the current through Y and Z when the suppressive impedance is a maximum. Let I_p = current in the suppressor circuit. The energy supplied to the suppressor is equal to the energy dissipated in the suppressor circuit, that is,

$$[I_{(min.)}]^2 \frac{Y^2}{R_y + R_z} = I_p^2(R_y + R_z) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (26)$$

From (26)

$$\frac{I_{(min.)}}{I_p} = \frac{R_y + R_z}{Y} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

and the potential E_s impressed upon the suppressor is

$$E_s = I_p Y \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (28)$$

$I_{(min.)}$ is in quadrature with I_p and is therefore doubly negligible compared to I_p.

SERIES AND PARALLEL RESONANCE WITH ZERO SERIES REACTANCE.

There is a second arrangement by which a suppressor may be introduced into an oscillatory circuit without changing the resonant frequency of the oscillatory circuit.

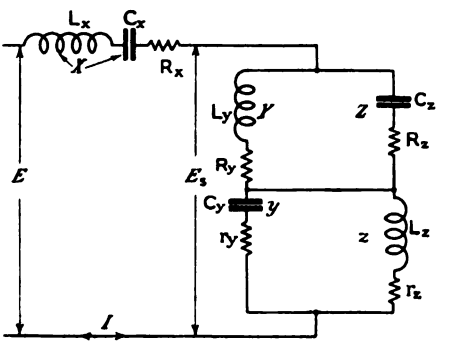

FIG. 2.

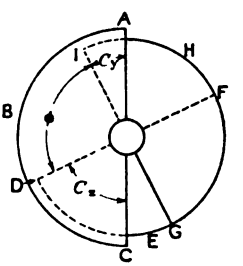

FIG. 3.

In Fig. 2 the suppressor comprises the suppressive reactances Y and Z and the compensating reactances y and z which have values to make the reactance of the suppressor zero at the series resonance frequency. The suppressive impedance is represented by

$$S = \frac{(R_y - jY)(R_z - jZ)}{R_y + R_z - j(Y + Z)} + \frac{(r_y - jy)(r_z - jz)}{r_y + r_z - j(y + z)}$$
$$= R_p - jP = R_p' + R_p'' - j(P' + P'') \quad . \quad . \quad . \quad . \quad . \quad (29)$$

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The value of R_p' in terms of Y, Z, R_y and R_z is similar to R_p in equation (5). Similarly, R_p'' in terms of y, z, r_y and r_z is similar to (5). The values of P' and P'' are expressed by equations similar to equation (6).

The condition for minimum impedance of the suppressor, Fig. 2, is $P' + P'' = 0$, that is,

$$\frac{YZ}{Y+Z} + \frac{yz}{y+z} = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (30)$$

For given inductances and capacitances the frequency which will satisfy equation (30) is

$$\omega_1^2 = \frac{L_y + L_z}{(C_y + C_z)L_yL_z} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

The condition for maximum impedance is the same as in Fig. 1, that is, $Y + Z = 0$ and the corresponding frequency is

$$\omega_\infty^2 = \frac{1}{L_yC_z} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (32)$$

It is seen by referring to equations (31) and (32) that there is a second method for obtaining series resonance at one frequency and then secure parallel resonance at another frequency without nullifying the adjustment for series resonance. This consists in adjusting C_z to secure the proper value of ω_∞ without changing the value of $C_y + C_z$.

Fig. 3 shows a practical method of adjusting C_y without varying $C_y + C_z$. Let ABC represent the fixed semi-circular plates of an air condenser. Let DEF be a set of rotatable semi-circular plates. Let GHI be a second set of rotatable semi-circular plates. Let DEF and GHI be rotatable with respect to each other and with respect to ABC. Fig. 3 therefore represents two air condensers of the usual type having shafts on a common axis. Let C_z represent the capacitance between ABC and DEF. Let C_y represent the capacitance between ABC and GHI. The capacitance $C_y + C_z$ can be adjusted to any value by rotating DEF with respect to GHI, that is, by varying the angle ϕ. For a given value of $C_y + C_z$ the capacitance C_y can be varied while ϕ remains constant.

This form of zero-reactance suppressor has greater suppressive impedance than a parallel zero reactance arrangement but it introduces more resistance into the circuit. It practically doubles the resistance to secure the advantages of simultaneous zero reactance and adjustability for maximum impedance.

NUMERICAL EXAMPLE.

A comparison of the arrangement of Figs. 1 and 2 can be best made by referring to Table 1, which is a tabulation of suppressive resistance, reactance and impedance for assumed values of frequency, inductance, capacitance and ohmic resistance. Let the series resonance frequency $\omega_1 = 10^6$ and the parallel resonance frequency $\omega_\infty = 9 \times 10^5$. Assume in Fig. 1 that $Y = 100 - 100 = 0$ ohms, when the series resonance frequency $\omega_1 = 10^6$ which corresponds to $L_y = 0{\cdot}1$ millihenry and $C_y = 0{\cdot}01$ microfarad. Assume resistance R_y of L_y and C_y in series to be 1 ohm. Assume

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$Y + Z = 0$ when $\omega_\infty = 9 \times 10^5$ which corresponds to $L_z = \frac{19}{81} \times 10^{-1}$ mH and $C_z = \infty$. Assume $R_z = 0{\cdot}2$ ohm. The wavelength λ is given in metres.

The suppressor circuit of Fig. 2 is the same as in Fig. 1 including the total ohmic resistance; therefore $L_y = 1\frac{19}{81} \times 10^{-1}$ mH and $C_z = 0{\cdot}01$ μF. Assume $R_y = 1$ ohm and $R_z = 0{\cdot}2$ ohm. Assume $L_z = 0{\cdot}1$ mH then from (31) $C_y = 0{\cdot}0081$ μF for minimum suppressive impedance when $\omega_1 = 10^6$. Assume $r_z = 1$ ohm and $r_y = 0{\cdot}2$ ohm.

TABLE I.

$\omega \times 10^{-4}$	λ	Fig. 1.				Fig. 2.						
		R_p	P	S	$\frac{YZ}{Y+Z}$	$R_{p'}$	P'	R_p''	P''	R_p	P	S
102	1,848	0·74	−3·42	3·50	3·40	16·4	442	33·3	−646	50	−204	210
101	1,866	0·85	−1·87	2·05	1·84	19·5	480	26·1	−580	46	−100	110
100	1,885	1·00	−0·05	1·00	0	23·7	525	20·8	−525	44	0	44
99	1,904	1·20	2·14	2·45	−2·20	29·2	580	16·8	−480	46	101	111
98	1,923	1·48	4·82	5·04	−4·90	37·0	649	13·7	−441	51	209	215
97	1,943	1·88	8·19	8·40	−8·32	48·4	738	11·3	−407	60	330	336
96	1,963	2·5	12·6	12·9	−12·8	65·9	855	9·4	−378	75	476	482
95	1,984	3·5	18·7	19·0	−19·0	94·8	1,018	7·9	−353	103	665	673
94	2,005	5·4	27·6	28·1	−28·2	148	1,259	6·6	−330	154	928	941
93	2,027	9·5	42·0	43·1	−43·5	260	1,651	5·6	−310	266	1,341	1,367
92	2,049	20·7	68·8	71·8	−73·9	569	2,388	4·7	−292	574	2,095	2,173
91	2,071	70·4	129·7	147·6	−163·9	1,955	4,072	4·0	−276	1,958	3,796	4,272
90	2,094	371·5	−14·1	371·5	$\mp\infty$	10,288	74	3·4	−262	10,292	−188	10,292
89	2,118	71·9	−162·0	177·2	196·7	1,977	−4,015	2·8	−248	1,980	−4,264	4,701
88	2,142	22·3	−106·6	108·9	105·8	579	−2,333	2·4	−236	581	−2,569	2,634

Table I. is self-explanatory. Among other interesting facts it shows the low resistance introduced into the series resonance circuit in Fig. 1 and the high suppressive impedance introduced into the circuit of Fig. 2. The reactance of a suppressor determines the impedance except when the reactance is zero; the reactance is zero at practically both minimum and maximum impedance. The reactance has a positive and negative maximum value when ω is slightly greater or less than ω_∞. Let $R_z = R_y$ in (6) then the maximum value of P' as ω is varied occurs when $\pm (Y + Z) = 2R_y$.

The suppressor of Fig. 1 should be used where minimum resistance is the most important factor. The suppressive impedance of Fig. 1 can be made to approach that of Fig. 2 by increasing the ratio of inductance to capacitance of the suppressor circuit; this increases the resistance for series resonance and the ratio is limited in practice by the distributive capacitance of the inductance coil or spiral. Research work is required to determine the best form and size of coil for minimum ratio of resistance to inductance for a given distributive capacitance; also the arrangement for maximum value of the ratio of maximum to minimum impedance in any particular case.

The suppressor of Fig. 2 should be used where maximum suppressive impedance is required. The addition of the compensating reactances, y and z, nearly doubled the resistance introduced at series resonance; this resistance can be reduced by making $C_y = 0$ and $L_z = 0{\cdot}5$ mH but at the sacrifice

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of adjustability. The series resonance resistance of the suppressor can be further reduced by omitting the compensating reactances when only one fixed wavelength is to be suppressed.

In Fig. 2 the suppressor introduces two additional frequencies at which series resonance takes place and one additional frequency at which parallel resonance occurs.

SUPPRESSION OF INTERFERING CURRENT IN AN AERIAL CIRCUIT.

Parallel resonance is especially useful in suppressing an undesired frequency current in an aerial circuit. A zero-reactance suppressor introduces a relatively small ohmic or effective resistance into the aerial circuit for received signal current but a high effective resistance to interfering current.

Fig. 4 shows an antenna circuit arrangement in which the signals from two stations are being received and two interfering signals are being suppressed. The zero-reactance suppressors S_1 to S_6 are either as shown in Fig. 1 or in Fig. 2.

Let the wavelengths λ_r' and λ_r'' be received by receivers 1 and 2 respectively and let the interfering wavelengths be λ_i' and λ_i''. Then S_1, S_3 and S_4 are a minimum for λ_r' and S_2, S_5 and S_6 are a minimum for λ_r''. S_1 is a maximum for λ_r'' and S_2 is a maximum for λ_r'. S_3 and S_5 are maximum for λ_i' and S_4 and S_6 are maximum for λ_i''. Opening a switch introduces a low resistance to one frequency current and a high resistance to another frequency current. Any number of zero-reactance suppressors may be placed in series or in parallel. Suppressive impedances S may be treated mathematically as non-inductive resistances having either small or large values. As the ratio

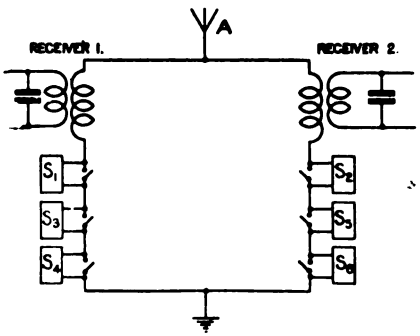

FIG. 4.

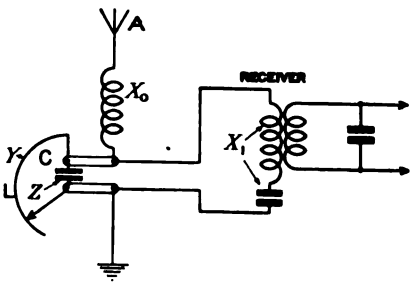

FIG. 5.

of L to C of a suppressor circuit decreases the energy consumed by the suppressor increases and the suppressive impedance decreases. Each suppressor introduces at least one additional resonant frequency into the series resonance circuit. Each suppressor can be graduated in wavelengths for minimum impedance and graduated in arbitrary units for interfering wavelengths. The interfering wavelengths corresponding to the arbitrary

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units for each received wavelength can be tabulated for reference. For duplex sending transmitters are substituted for the receivers.

SELECTIVITY.

The selectivity secured and the energy absorbed from waves by an aerial circuit is greatly increased by series resonance. Selectivity can also be attained by parallel resonance. Fig. 5 shows an arrangement by which the selectivity of a series resonance circuit is increased by means of a parallel resonance circuit.

In Fig. 5 the parallel resonance circuit consists of a small inductive reactance Y and a small capacitive reactance Z. The inductance L is very small and the capacitance C is very large.

The parallel resonance circuit is connected in parallel with the reactance X_1 to which the receiver is coupled. At the wavelength λ_r which is being received $X_0 = X_1 = Y + Z = 0$ where X_0 is the reactance of the antenna circuit. For λ_r the impedance of X_0 and X_1 is a minimum and the impedance of the shunted suppressor is a maximum. Nearly all the signal current flows through X_1 and little through Y and Z. For an interfering wavelength λ_i the impedance of X_0 and X_1 is large while the impedance of the shunted suppressor is much less than for λ_r. The parallel reactances Y and Z constitute a by-pass or diverter for the current of all wavelengths differing from λ_r. The efficiency of the shunted suppressor as a divertive reactance increases as the product of positive reactance Y and negative reactance Z decreases, that is, as the ratio of L to C decreases.

The divertive reactance S_d of the diverter, for all wavelengths differing from λ_r sufficiently to make the effective resistance negligible compared to the reactance, is

$$S_d = \frac{YZ}{Y+Z} = \frac{K\lambda_i}{\lambda_r^2 - \lambda_i^2} \cdot L \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (33)$$

where K is a constant. The impedance S_d for λ_r is expressed by equation (16) and for any interfering wavelength λ_i the divertive reactance is given by (33). As the ratio of L to C decreases the selectivity is increased but the received signal intensity becomes less because the suppressive resistance of the diverter is reduced and a larger part of the signal current passes through the diverter. The selectivity due to series resonance is increased by *increasing* the ratio of L to C but intensity of the signal is decreased due to the increase of resistance in the antenna circuit. The ratio of S_d for λ_i to S_d for λ_r varies directly as the damping factor of the diverter circuit, that is, as the resistance of L and C in series divided by $2L$. The leads to the diverter should not be allowed to inductively affect L.

By tuning X_1 and the diverter to λ_r and detuning X_0 from λ_r the signal-stray ratio can be greatly increased but at a great sacrifice of received signal intensity.

Fig. 6 shows a combination of suppressors and diverters. The suppressive resistance of S_1 is a maximum for the wavelength λ_r selected for reception and is a minimum for the transmitted wavelength λ_t. The suppressors S_2, S_3

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and S_4 are similar and have a maximum R_p for λ_t and a minimum R_p for λ_r. The diverters D_1 to D_3 are tuned to λ_r. The arrangement of S_2, S_3 and S_4 is equivalent to one suppressor having an increased ratio of L to C and D_1, D_2 and D_3 is equivalent to a diverter having a decreased ratio of L to C. Two

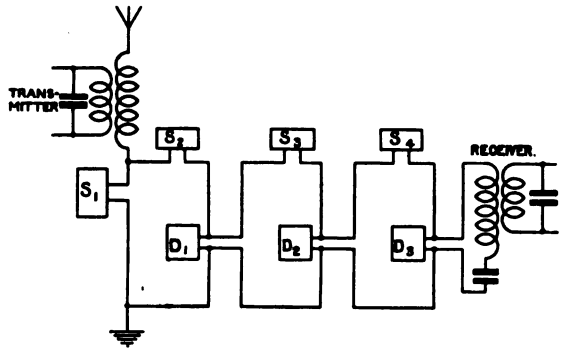

FIG. 6.

suppressors connected in series and tuned to the same interfering wave are equivalent to one suppressor with a larger ratio of L to C.

QUALITY OF WAVES.

Suppressive impedance and selectivity are determined by sharpness of resonance which depends upon the resistance and ratio of inductance to capacitance of the resonant circuit of the receiver and upon the quality of wave emitted by the transmitter. When further increase in sharpness of resonance is limited by poor quality of waves improvement in the receiver is useless. The three principal factors which determine the quality are: (1) The rate of change of amplitude, (2) the constancy of wavelength, and (3) the distortion of wave-form from a sine wave.

Suppressive impedance decreases as the rate of change of amplitude of the interfering wave increases; it decreases as the ratio of energy dissipated to the energy stored in, or withdrawn from, the suppressor circuit decreases. In other words, the counter E.M.F. of the suppressor is too low while the amplitude is increasing rapidly and too large while the amplitude is decreasing rapidly.

The beginning and ending of a dot or dash of telegraphic signals permits generally a large rate of change of amplitude. This difficulty can be largely overcome by changing the frequency of beats to produce signals, gradually increasing and decreasing the amplitude of current, or both. The rate of change of amplitude due to speech in telephony is too small to appreciably reduce sharpness of resonance at short wavelengths.

Maximum impedance depends upon a definite frequency and any variation reduces the impedance. Reference to Table I. will show the decrease as the frequency varies.

Distortion of the wave-form from a sine wave reduces the maximum suppres-

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sive impedance because the instantaneous counter E.M.F. of the suppressor must be of the same form as the impressed E.M.F.; the former is practically a pure sine wave. In order for a transmitted wave to be a pure sine wave the instantaneous rate at which energy is transferred to an antenna circuit during a complete cycle must equal the instantaneous rate at which energy is dissipated in the antenna circuit by radiation and losses; this cannot be realised in practice. The constant amplitude waves of high frequency alternators, Poulsen arcs and thermionic current oscillators approach a sine wave.

A standard method should be adopted for comparing the quality of waves. The present standard of damping factor or logarithmic decrement of a damped wave is a measure of one form of rate of change of amplitude. As interference from other stations becomes more common and the use of constant amplitude waves becomes more general the need for a more general and exacting standard becomes more urgent. Fig. 7 is suggested as an arrangement which will meet the requirements.

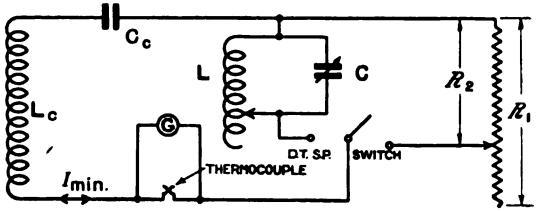

FIG. 7.

Fig. 7 is an arrangement of a wave tester comprising an inductance L_c which is very loosely coupled to the transmitter of the wave to be tested, a suppressor LC, a thermocouple and galvanometer G to measure the suppressed current $I_{(min.)}$. The non-inductive resistance R_1 is equal to the suppressive resistance of LC for a sine wave and R_2 is equal to the suppressive impedance of LC for the wave to be tested. The values of R_1 and R_2 are determined by throwing the double throw switch without changing the deflection of the galvanometer. The large condenser C_c stops D.C. flowing through L_c from the thermocouple. The ratio of R_2 to R_1 is a measure of the quality of the wave. The value of R_1 can be either measured with a sine wave current or calculated from the constants of the suppressor by equation (16). The only part in this arrangement which would require standardisation is the suppressor circuit.

Suppressive impedance as a standard has decided advantages when compared with a minimum impedance standard or a standard of maximum current I_p in the suppressor circuit. Minimum impedance depends upon the measurement of a small resistance and impedance which approaches zero instead of infinity as a pure sine wave is approached. The maximum value of I_p varies directly with the square root of the suppressive resistance R_p; both I_p and R_p depend upon the small resistance $R_y + R_z$ of the suppressor

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circuit. It is difficult to measure I_p without adding an effective resistance to $R_y + R_z$ due to the withdrawal of energy from the suppressor circuit. Furthermore, both the suppressor and method of measuring I_p would have to be standardised.

REFERENCES.

Among the few references available the following are briefly noted. The most complete is the *U.S. Bureau of Standards Circular No.* 74 which deals principally with variation of reactance with frequency and not with impedance. The apparently simple fact that $U = 0$ when $X = Y = 0$ was overlooked although the special case (pp. 50 and 62) is noted that $U = 0$ when $C_x = C_y$ and $L_x = L_y$ and that the zero value of U is then independent of the value of Z.

In the *Proceedings of the Institute of Radio Engineers* for December, 1919, F. A. Kolster proposes a suppressive impedance to suppress an undesirable harmonic in a Poulsen arc transmitter. The proposed suppressor comprises three tungsten lamps and the suppressor circuit is termed a "sucking out" circuit because it is believed that suppressive impedance is due to absorption of energy by the lamps. Reference to equation (16) discloses the error.

The impedance of a parallel resonance circuit to an electrical impact in the series resonance circuit is correctly stated by J. H. Morecroft, in the *Proceedings of the Institute of Radio Engineers* for February, 1920, to be very small. This is due to the large rate of change of amplitude and no resonance effects.

The use of a divertive reactance was described by J. S. Stone in U.S. Patent No. 884108, filed in 1906, but the subject has apparently been ignored by radio publications since that date.

BREMERTON, WASH., U.S.A.
November, 1920.

German Developments in C.W. Stations.*

One of the minor results of the war has been that the German telegraphic lines are either in a bad state of repair or completely out of service. In consequence of this and of the growing commercial demands the Telegraph Department have erected a considerable number of medium power radio stations designed to replace in part the imperfections of the wire telegraph system. At the present time these stations are handling considerable traffic. Several of them operate on continuous waves using valve oscillation generators working on wavelengths between 900 and 2,500 metres. The most important stations are set out in the table below which also gives their wavelength and the system of operation.

Of these the most interesting are the recently developed 1 kW C.W. stations which are operated with valve oscillation generators. These

* Abstracted from *La T.S.F. Moderne*—see Abstract No. 2094 in this issue for reference.

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stations are divided into three main parts—the transmitting unit, the receiving unit, and the power unit.

Locality.	Call Sign.	Wavelength.	Type of Transmission.
Munich	C W	1,200	Quenched spark.
Darmstadt	D A	1,725	C.W. valves.
Berlin Wolff	D K	2,100	do.
Berlin	D M	1,900	do.
Dortmund	D R	1,400	do.
Friedrikshafen	F D	?	do.
Frankfort-on-the-Maine	F M	1,975	do.
Frankfort-on-the-Oder	F_4	1,200	Quenched spark.
Stettin	G M	1,200	do.
Hamburg	H G	2,100	C.W. valves.
Hanover	H W	2,300	do.
Constance	K N	1,450	do.
Königsberg	K O	2,500	do.
Leipzig	L Z	1,100	do.
Magdeburg	M A	1,200	Quenched spark.
Neuenmunster	O K	1,200	do.
Staaken	S K	?	C.W. valves.
Hanover	S F	1,200	Quenched spark.
Stettin	S N	1,800	C.W. valves.
Stuttgart	S G	1,200	Quenched spark.
Frankfort-on-the-Maine	W H	1,200	do.
Munster Rühr	W I	1,200	do.
?	W U	1,200	do.
Nuremberg	X I	1,200	do.
Cassel	X U	1,200	do.

The transmitter is made up into four boxes containing respectively the valves and their filament circuits, the grid and plate coils, the aerial tuning inductance and variometer, and the aerial shortening condensers.

For this transmitter two 500 watt three-electrode valves are employed. These valves are carefully constructed without any internal soldering or welding, the plate being rivetted to its support. The filament is V-shaped and is maintained in tension by a spring. The grid is wound around four metallic supports arranged at the corners of a square of one inch side while the plate is in the form of a cylinder of about $1\frac{1}{2}$ inches diameter. The external dimensions of the valve which is roughly cylindrical in shape are approximately 10 inches high by 3 inches diameter. The filament requires five amperes at 15 volts to heat it.

Transmission may be effected in either of two ways, using a rectified alternating current or plain alternating current for the plate circuit supply,

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the latter giving a tonic train emission. In the actual installation a special switch is provided for quickly changing from one to the other arrangement.

The general scheme of connections of the transmitting unit is given in Fig. 1 from which it may be noted that the two valves are used in parallel, and that the filament circuit of each is fed from an independent transformer.

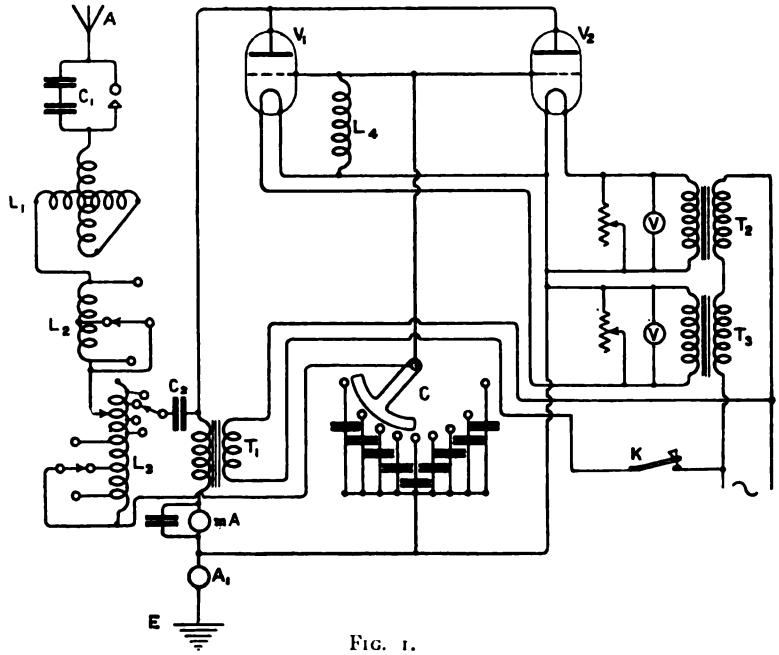

FIG. 1.

In this diagram only the A.C. plate circuit supply for tonic train emission is indicated but when rectified A.C. is employed the transformer T is replaced by the condenser in which the rectified pulses are stored up.

The supply for the plate circuits and for the filament is drawn from the same alternator as indicated in the diagram. The temperature of the filaments can be regulated by means of the rheostats shown. For smoothing out the irregularities in the rectified current eight condensers of two microfarads each are joined in series, the supply for the three-electrode valves being taken from their terminals. For reducing the wavelength of transmission condensers C are arranged so that a variable number may be inserted in the earth connection. The normal aerial current is about 5 amperes.

For reception a two-valve low frequency amplifier is employed using the same aerial as is also employed for transmission.

In each station two power units are fitted one for normal operation and the other a spare. The power unit consists of a 110 volt motor driving a 500 cycle 220 volt alternator from which the valve supply is drawn in the manner indicated above.

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A Peculiar Electrostatic Phenomenon.

A lecture describing a peculiar electrostatic phenomenon was given at an ordinary meeting of the Institution of Electrical Engineers by Messrs. A. Johnsen and K. Rahbek on May 26th. The lecturers described apparatus developed by them from experiments commenced in 1917 on the properties of semi-conducting materials. By placing a slab of such a material between the plates of a condenser—one plate being in the form of a disc 2″ diameter suspended from the arm of a balance—it was shown that when a potential of 400 volts was applied to the plates, it required a weight of over a kilogram to pull the disc away from the material. The current flowing through the apparatus was extremely minute.

The effect appears to be due to the formation of a layer of ions on the surface of the semi-conducting material, so that the small distance separating this layer from the metal disc resting on it accounts for the large attracting force. If the semi-conductor is made up in the form of a disc or cylinder on the surface of which one metal electrode rests, the attractive force called into play when a potential is applied gives rise to an increased friction between the metal and the material if the latter is maintained in rotation by a suitable motor.

Applications of this apparatus to "no-volt" relays, to telegraphic recorders and to loud-speaking telephones were described. A demonstration was given of a violin used as a loud speaker by attaching to it an agate cylinder round which was wrapped a metal band attached to the body of the violin, the reproduction of both music and speech being very clear and loud. Many materials have the property of showing these effects, and in particular lithographic stone, slate, and agate may be mentioned.

Long Distance Wireless Transmission.

A discussion on this subject took place at a meeting of the Wireless Section of the Institution of Electrical Engineers on May 25th. The discussion was opened by Mr. C. F. Elwell who reviewed the theoretical and experimental work on the subject and maintained that there was no reliable data for the determination of the power required for distances and wavelengths beyond those covered by the experiments of Austin. He thought that amateurs could assist in collecting data. Admiral Sir Henry Jackson regarded the measurements as too difficult for amateurs, but emphasised the necessity for such measurements being made. Messrs. Round, Eckersley and Lunnon described the work being done by the Marconi Company at Chelmsford using a carefully calibrated aerial 16 metres high and determining by a substitution method the E.M.F. induced in it by some of the large American transmitting stations. Although varying considerably the average E.M.F. was 1·8 times that given by the Austin-Cohen formula. The measured E.M.F. agreed fairly well with the field strength of 0·37 microvolts per cm which we assumed as the basis for the tables of necessary transmitting power (see RADIO REVIEW, 1, p. 598, September, 1920).

Captain Lee described somewhat similar measurements made by the Radio Communication Company using a 4-foot frame with 120 turns; preliminary tests have given a field strength of 0·2 microvolts per cm for the signals from Annapolis. Several speakers mentioned that the signals from these American stations are weaker during the night than during the day, although for stations in other directions the reverse is true.

G. W. O. H.

Notes.

Personal.

Mr. F. Golding, Director of Radio Services in the Commonwealth of Australia Postal Department, has been appointed by the Commonwealth Postmaster-General as a commissioner to visit the United States, Canada, Britain and the Continent.—*Sydney Morning Herald.* [2580]

An announcement has recently been made that the following French radio engineers have been nominated Chevaliers of the Legion of Honour for their inventions :—

J. Bethenod (high-frequency alternators).
E. Bloch (applications of vacuum tubes to radiotelegraphy).
L. Bloch (applications of vacuum tubes to radiotelegraphy).

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A. Dufour (cathode ray oscillograph).
M. Latour (high-frequency alternator; theoretical studies of vacuum tubes and their application to radiotelegraphic communication). [2608]

The Albert Medal of the Royal Society of Arts for 1921 has been awarded by the Council, with the approval of the President, H.R.H. the Duke of Connaught and Strathearn, K.G., to **Professor John Ambrose Fleming**, M.A., D.Sc., F.R.S., in recognition of his many valuable contributions to electrical science and its applications, and specially of his original invention of the thermionic valve, now so largely employed in wireless telegraphy and for other purposes.

The Medal was instituted in 1862 as a memorial of H.R.H. the Prince Consort and is awarded annually for "distinguished merit in promoting Arts, Manufactures and Commerce." [2999]

The Times announces the death of **Dr. Edward B. Rosa**, Chief Physicist at the Bureau of Standards, Washington, U.S.A., on May 17th. One of America's leading scientists he was known to scientific men in England from his attendance at meetings of the British Association, and by his numerous publications on electrical investigations. [2734]

Mr. George S. Davis, who is in charge of the Radio Service of the United Fruit Company, has been elected a director of the Radio Corporation of America. Mr. Davis is also President of the Wireless Specialty Apparatus Company of Boston, Mass. [2753]

Dr. F. B. Jewett, Chief Engineer of the Western Electric Company, U.S.A., has been elected a Vice-President and Director of that Company, but he will continue his present duties in charge of the Technical Department. During the war he was a Lieut.-Colonel in the U.S. Signal Corps and was decorated with the D.S.M. [2754]

Commander R. L. Nicholson has been appointed Director of Wireless Telegraphy in India in succession to Colonel A. Simpson. [2789]

H. Bredow has been appointed Secretary of State to the Ministry of Posts, for the whole of the telegraph, telephone and wireless services of Germany. [2863]

Commercial.

It is reported that the concession recently given to Marconi's Wireless Telegraph Company for operating the Peruvian wireless and land line telegraph service for twenty-five years has been made the subject of representations by the United States Government. [2742]

The balance sheet of the Radio Corporation of America at December 31st shows the following:—Assets, cash and receivables, $881,507; merchandise inventories, $689,516; investments in Government and industrial bonds, $3,375,210; stocks of associated companies, $550,385; plant and equipment, $8,901,675; deferred charges, $606,669; patents and goodwill, contracts and franchises, $10,107,982. Current liabilities are $1,883,227. [2650]

WIRELESS EQUIPMENTS ON SWEDISH VESSELS.—It is stated that the operation of the British Merchant Shipping Wireless Telegraphy Act which renders compulsory the installation of radio apparatus on all vessels over 1,600 tons is meeting with opposition in Swedish merchant shipping circles and that a petition has been forwarded to the Swedish Ministry of Marine to secure exemption from the operation of the Act until the end of the current year owing to difficulties in obtaining the necessary apparatus. [2653]

NEW WIRELESS PLANT FOR COLTANO.—A decree dated December 20th, 1920, refers to an agreement between the Italian Minister of Posts and Telegraphs and the Italian Minister of Marine for the reorganisation of the wireless installation at Coltano naval radio station. The station is to be handed over to the Minister of Posts and Telegraphs after reorganisation. [2646]

IMPERIAL WIRELESS SCHEME.—An announcement has been made that preliminary action has been taken for the selection of a site in Western Australia for the erection of a wireless station in connection with the Imperial Chain. [2648]

Lieut.-Colonel E. Gold, Assistant Director of the Meteorological Office, reports that it has been decided to establish a wireless station in Greenland for daily weather reports. Another development expected in the near future is the establishment of daily weather communications between Britain and Canada. [2730]

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New Wireless Services, etc.

A NEW WIRELESS SERVICE.—It is announced from Washington that a commercial wireless service has been established between the United States and the Dutch East Indies. [2651]

WIRELESS MESSAGES TO SHIPS—SIMPLIFIED PROCEDURE.—Post offices in London and the provinces will now accept wireless messages addressed to persons on ships at sea (which are within range of the coastal wireless stations of the United Kingdom) without requiring the sender to specify the station through which the message should be transmitted. This new arrangement removes what undoubtedly has been a serious obstacle to the free use of wireless telegraphy between this country and ocean travellers. [2731]

SIGNALLING RANGE OF THE EASTHAMPTON RADIO STATION.—We have received from the Cutting and Washington Radio Corporation, New York, an interesting chart showing some of

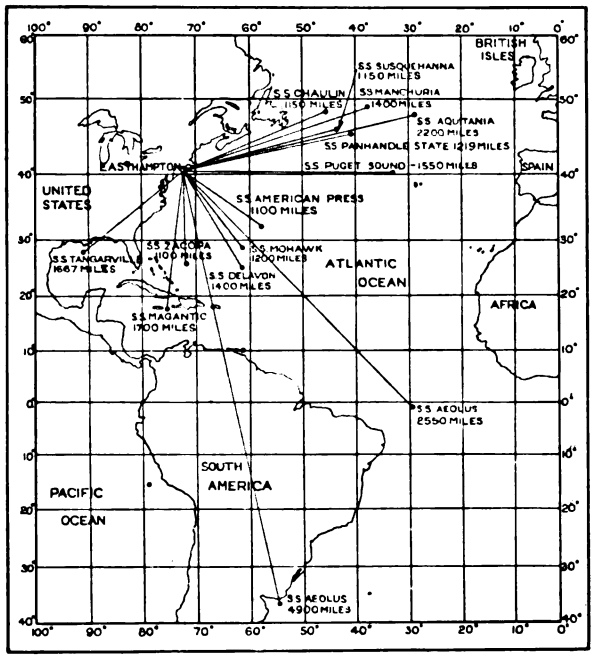

Chart of Long Range Communication by the Easthampton Station.

the long range communications that have been effected by their new coast radio station at Easthampton, L.I. A brief description of this station was published in our issue of February, 1921, and the chart reproduced herewith shows that signals from the station have been heard over a range of 4,900 miles. [2644]

WIRELESS FOG SIGNALS.—The Secretary of Commerce, U.S.A., announces that three wireless fog signals are to be immediately installed at the entrance to New York Harbour. Each of these three stations will be equipped with an automatic set which will send out signals continuously during fog or thick weather. These signals may be picked up on shipboard by means of a radio compass so that, by taking observations on the different stations, the captain of a vessel may determine his exact position. The method has been developed as the result of co-operative experiments by the Bureau of Standards and the Lighthouse Service. The sending apparatus is easily installed and can be operated by the regular light keepers without any skilled personnel. [2729]

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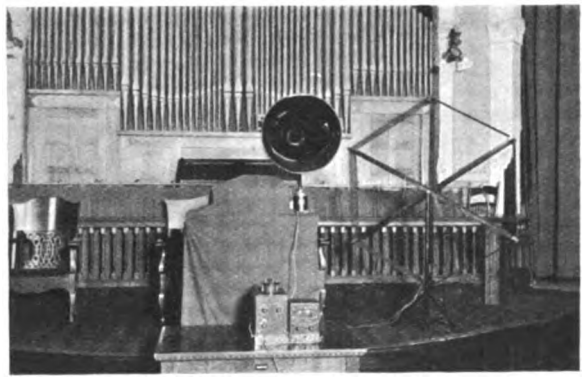
WIRELESS TELEPHONY EXPERIMENTS IN FRANCE.—Some experiments with wireless telephonic apparatus have recently been made between Sainte-Assise (near Melun) and Beauvais. Transmission and reception were effected by means of valve sets manufactured by the Société Française Radioélectrique using a transmitting energy of not more than 5 watts. The distance between the two stations is 120 km. [2847]

RECEPTION OF RADIO SIGNALS IN ARGENTINE.—As a preliminary measure in connection with the proposed establishment of direct wireless communication between Germany and Argentine, engineers of the Telefunken Company have been making experiments in the reception of signals from Nauen at various points in Argentine. Further experiments are to be made with improved receiving apparatus during the present year. Whereas in June the atmospheric disturbances were equal in strength to the signals, they became steadily worse until in November they were seven or eight times as strong as the signals as measured in ohms in parallel with the telephone receiver. During November reception was possible on only ten days. The experiments were made with a frame coil of 30 metres side carried from a 50 metre mast. [2887]

For the first time, so far as is known, wireless telephony has been used to transmit services from one church to another in order that a congregation without a regular pastor could have the benefits of Sunday evening worship. The churches involved in this test were the Calvary



A Sermon by Wireless in U.S.A.

Episcopal and the Herron Avenue Presbyterian, both of Pittsburg, Pennsylvania, U.S.A., and for several months past the Sunday evening services of the former church have been broadcasted by radio from a test station in East Pittsburg. The arrangements were made by the Westinghouse Electric and Manufacturing Co. For reception a loop antenna, amplifier and condenser was placed on the rostrum in front of the pulpit. The loud speaking horn rested directly on the pulpit. The music, singing and sermon were clearly received in the second church. [3003]

It is stated in the *Elektrotechnische Zeitschrift* for March 10th, 1921, that successful experiments have been made in the application of the Siemens high-speed printing telegraph to wireless telegraphy between Berlin and Leipzig. For five days the whole traffic was carried in this way during the hours of the experiment. [2888]

The station at Deutsch-Altenburg was opened in August, 1920. Built by the Telefunken Co. on similar lines to the station at Pola, *i.e.*, with high-frequency alternator and frequency transformers, with an aerial power of 50 kW, it has three alternative wavelengths, viz., 7,500, 5,000, and 3,750 metres. The station was ordered in 1915 by the Austro-Hungarian Government and intended for a range of 2,000 to 3,000 km. [2889]

The Lizard wireless direction-finding station is to be reopened after the aerial system has been reconstructed. [2743]

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RADIO TRAFFIC ON THE AMERICAN SEABOARD.—In order to avoid unnecessary calls and interference an agreement has been made between the companies operating the stations set out below to observe certain rules in the handling of traffic and unnecessary repetition of signals. The shifting of the wavelength from 600 metres to 300 or 450 metres is also recommended for handling the traffic after the initial calling has been effected. Alternative wavelengths suggested for handling all traffic are 1,800 and 3,000 metres when these are licensed :—

WSA	Easthampton, Long Island, N.Y.
WCY	Cape May, New Jersey.
WCG	Brooklyn, New York.
WLC	New London, Connecticut.
WSC	Sisconset, Massachusetts.
WCI	Newport, Rhode Island.
WNN	Belfast, Maine (now under construction).
WSE	Babylon, Long Island, N.Y.
WBC	East Moriches, Long Island, N.Y.
WNY	New York, N.Y.
WST	Rockland, Maine.
WBF	Boston, Massachusetts. [2843]

The radio direction-finding station **FEC** at Brest-Capucins has been replaced by the station Brest-Moulin du Seigneur, which has the call letters **FEI.** The wavelengths used are 450, 600 and 800 metres and the range of the station is about 105 nautical miles. [2848]

Review of Radio Literature.

1. Abstracts of Articles and Patents.

(H.) Radio Receiving Apparatus.

(3) SPECIAL ELECTRON-TUBE DETECTORS AND RECEIVERS.

1988. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Valve Detector. (*French Patent* 506987, April 14th, 1919. Published September 2nd, 1920.)

The received oscillations are conveyed to an auxiliary controlling grid, whereby the value of the negative resistance of the vacuum tube is varied. The external circuit of the cathode and the plate contain an inductance and a capacity in parallel and so adjusted that the circuit is resonant to the received frequency. For further particulars see *British Patent* 117283.

1989. **H. Fassbender** and **E. Habann.** Audion Receiver. (*German Patent* 312587, August 30th, 1918. Patent granted December 12th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 383, November, 1920—Abstract.)

A valve circuit in which the condenser in the grid circuit is placed in parallel with a resistance of sufficiently high self-inductance.

1990. **E. H. Armstrong.** Recent Progress in Reception with the Audion. (*La T.S.F. Moderne*, 1, pp. 133—144, August; pp. 169—175, September; pp. 215—221, October; pp. 250—287, November; pp. 291—298, December, 1920.)

A translation of an article which was first published in the *Proceedings of the Institute of Radio Engineers* in September, 1915.

(4) HETERODYNE AND C.W. RECEIVERS.

1991. **M. Adam.** The Reception of Undamped Waves—The Tikker and the Heterodyne Method. (*Radioélectricité*, 1, pp. 305—309, November; pp. 355—361, December, 1920.)

Includes details for constructing a heterodyne set.

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1992. **M. Latour.** The Heterodyne Method of Wireless Reception: Its Advantages and its Future. (*Bulletin de la Société Française des Électriciens*, 10, pp. 363—374, November, 1920. *Radioélectricité*, 1, pp. 335—340, December, 1920.)

Paper read before the Société Française des Électriciens. See RADIO REVIEW, 2, pp. 15—21, January, 1921, where the full paper was printed.

1993. **T. G. Thornblad (Svenska Radioaktiebolaget).** Continuous Wave Receivers. (*British Patent* 143857, May 21st, 1920. Convention date May 23rd, 1919. Patent not yet accepted.)

Relates to a C.W. receiver in which the capacity of a condenser is varied at an audible frequency. The condenser may be included either in the high-frequency circuits or may be charged by the rectified current impulses from an ordinary pattern of detector.

1994. **M. Latour.** A New Generator for the Heterodyne. (*Wireless Age*, 8, p. 21, December, 1920. *Science Abstracts*, 24B, pp. 157—158, Abstract No. 311, March 31st, 1921—Abstract.)

An evacuated bulb is used containing a small quantity of mercury which serves both as an anode and as vapour emitting metal. An incandescent filament is used as a cathode. It has been experimentally verified that the characteristics of the discharge in the mercury vapour in this arrangement are those of the arc, that is the apparatus behaves as a negative resistance and sets up sustained oscillations in a shunt inductance-capacity circuit.

1995. **E. Roger.** The Tikker for the Reception of Undamped Waves. (*La T.S.F. Moderne*, 1, pp. 195—197, September, 1920.)

An illustrated description of the instrument manufactured by Ateliers Ducretet, E. Roger successeur, Paris.

(5) RELAYS, RECORDERS AND AUTOMATIC CALLING APPARATUS.

1996. **M. Latour.** Relay. (*French Patent* 503936, December 5th, 1917. Published June 21st, 1920.)

The apparatus employs two or more thermionic relays and further particulars may be obtained from the corresponding *British Patent* No. 140506. See Abstract No. 897, October, 1920.

1997. Automatic Printing of Wireless Messages. (*Discovery*, 2, pp. 49—50, February, 1921.)

A brief summary of the automatic printing apparatus developed for wireless reception by Messrs. Creed & Co., Ltd., of Croydon. (See also RADIO REVIEW, 2, pp. 37—38, January, 1921.)

1998. **R. D. Doner.** The Hall Jet Relay for Recording Radio Signals. (*Science and Invention*, 8, pp. 1099 and 1130, February, 1921.)

A description is given of this recording apparatus in which a jet of air is influenced by the sound waves from a telephone connected to the receiving apparatus. The resulting change in the form of the jet affects the cooling of a spiral of hot wire on which the jet impinges. The recorder is operated by the resulting changes in the resistance of the wire. A sample of received slip is given.

(I.) Amplifiers.

1999. **J. K. Catterson-Smith.** The Design of Inter-valve Transmitters. (*Electrician*, 85, pp. 388—390, October 1st; pp. 414—416, October 8th, 1920. *Science Abstracts*, 23B, pp. 547—548, Abstract No. 1039, November 30th, 1920—Abstract. *Technical Review*, 8, p. 262, March 15th, 1921—Abstract.)

The procedure in designing iron core transformers for use with valve magnifiers differs very much from that employed for ordinary transformers. The article is concerned solely with the design of aperiodic amplifiers for low frequencies. A preliminary survey is given of the principle of operation of the valve as an amplifier followed by a consideration of an ideal inter-valve transformer having no magnetising current or loss. The effect of the magnetising

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current is then considered and expressions derived for the step-up in each stage of the amplifier for any value of the transformer reactance. Formulæ are given for the calculation of the inductance of winding and for calculating the leading core dimensions together with examples of their use. The final sections treat of the modifications introduced when an auto transformer is used for coupling the valves; and the similar problems of telephone transformers.

2000. **C. M. Minnis.** The Design and Construction of Audio Frequency Transformers. (*Wireless Age*, 8, pp. 26—27, February, 1921.)

Constructional details are given for building intervalve transformers for multi-stage low-frequency amplifiers.

2001. **R. Barthelemy.** The Calculation of the Intervalve Transformers for Low-frequency Amplifiers. (*La T.S.F. Moderne*, 1, pp. 97—103, July, and pp. 144—148, August, 1920.)

A mathematical consideration of the mode of operation of intervalve transformers for low-frequency amplifiers, with the derivation of design formulæ and curves.

2002. **L. Jacquot.** The Practical Construction of a Low-frequency Transformer Coupled Amplifier. (*La T.S.F. Moderne*, 1, pp. 103—109, July, 1920.)

Gives detailed dimensions for the construction of the necessary intervalve transformers.

2003. **M. Adam.** The Construction of a Resistance Amplifier. (*Radioélectricité*, 1, pp. 415—418, January, 1921.)

2004. **J. H. C. Harrold.** Thermionic Valves and their Application to Wireless Telegraphy. (*Radiograph*, 3, pp. 6—7, January; pp. 25—26, February; pp. 41—42, March, 1921.)

Short articles dealing with various types of high and low-frequency amplifiers.

2005. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Relay. (*French Patent* 507099, December 5th, 1919. Published September 4th, 1920.)

The specification describes an arrangement for amplifying potential variations comprising a particular arrangement of two and three-electrode valve tubes.

For further particulars, see *British Patent* 5373/1915.

2006. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Amplifier. (*French Patent* 507094, December 5th, 1919. Published September 4th, 1920. *British Patent* 129313, October 10th, 1917.)

A series of valve relays are employed for amplifying small currents and for minimising interference due to strays. Resistance-capacity couplings are used between the valves. The heterodyne oscillator for C.W. reception is shown coupled to the circuit of the receiving telephones, and it is suggested that when the valves are arranged to limit the intensity of incoming signals or X's, the successive intervalve coupling condensers should be of progressively increasing capacity. To further reduce atmospherics the aerial may be rendered aperiodic by inserting in series with it a resistance $= 2\sqrt{LC}$ where L and C = capacity and inductance of aerial respectively. The grid circuit of the first valve may be connected across the resistance and the plate circuit of the third valve tuned to the incoming signal frequency.

2007. **M. Pirani.** The Measurement of the Efficiency of Amplifiers. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 2—30, July, 1920.)

The author discusses the basis upon which it is possible to determine the efficiency of an amplifier. The results obtained in any case depend upon the amplifier itself and upon its adaptation to the input and output apparatus. The author leaves this adaptation to a subsequent occasion and deals only with the amplifier itself. Both low and high-frequency amplifiers are dealt with. In one method an oscillating triode is used as a source, the current passing through two resistances in series; the amplifier is supplied from the P.D. across one of these resistances or a known fraction of it, and the telephone receiver can be put alternately on to the amplifier and across the other resistance. The resistances can be varied until a sound balance is obtained. In another method artificial cable is inserted in one of the two paths and the effect of the amplifier expressed in terms of the attenuation thus introduced. The use of the Franke machine is also mentioned. The measurement of the resistance and

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inductance of low-frequency amplifiers by means of a bridge is also discussed and some results given. For stable note amplifiers with various numbers of triodes the author gives the following values for the power amplification :—1 triode 10—15 ; 2 triodes 150—200 ; 3, 1,000—1,500 ; 4, 4,000—6,000 ; 5, 20,000—25,000. Much greater values can be obtained by sacrificing stability. For high-frequency amplifiers, the oscillating triode was caused in any way to vary with audible frequency and its current was passed through two condensers in series ; the P.D. across one was supplied to the telephone receiver through an audion and that across the other through the amplifier ; the condensers were adjusted until a balance was obtained. A number of difficulties which arise in carrying out such measurements are discussed.

2008. **C. W. Heaps.** Amplification of Electric Currents in the Bunsen Flame. (*Physical Review*, 16, pp. 238—246, September, 1920. *Annales des Postes, Télégraphes et Téléphones*, 9, pp. 547—552, December, 1920—Abstract. *Revue Générale des Sciences*, December, 1920—Abstract. *Engineering*, 110, p. 554, October 22nd, 1920—Abstract.)
The full paper corresponding to Abstract No. 520, July, 1920.

2009. **L. W. van Slyck.** An Electrolytic Amplifier. (*Wireless Age*, 8, pp. 22—23, January, 1921.)
The arrangement consists of an electrolytic cell having one electrode constructed of fine Wollaston wire which is vibrated in contact with the electrolyte by means of an appropriate electromagnet connected to the receiving circuits.

2010. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Relay. (*French Patent* 506591, November 26th, 1919. Published August 25th, 1920.) Also **A. W. Hull.** (*British Patent* 147149, July 7th, 1920—Convention date, November 8th, 1915. Patent not yet accepted but open to inspection.)
Electrical impulses which are to be amplified are applied to an ordinary resistance and a " negative resistance " in parallel, much greater current variations being thereby produced in each of the resistances. A three-electrode type of valve is employed with a higher positive potential upon the grid than upon the anode. The ordinary or positive resistance is connected between the anode and the intermediate point on the H.T. battery, and the output circuit or current utilising device is connected in series or parallel with the positive resistance. The positive resistance may be formed by the secondary of the input transformer.

(J.) Subsidiary Radio Apparatus (Power Rectifiers; Protective Apparatus; Telephones; Materials, etc.).

2011. **V. J. F. Bouchardon** and **M. A. Lesage.** Rectifier. (*French Patent* 505592, October 30th, 1919. Published August 2nd, 1920.)
The rectifier described is for high pressures of the order of 30,000 to 100,000 volts and the incandescent filament and the anode are mounted a considerable distance apart in the tube, so that reverse currents are avoided.
There is a corresponding British Application No. 153295, of October 12th, 1920 (Convention date October 30th, 1919), the patent on which has not yet been granted.

2012. **Société Anonyme des Etablissements H. Pilon.** Rectifier. (*French Patent* 506978, April 9th, 1919. Published September 2nd, 1920.)
In rectifying high-tension alternating currents the valve is connected at the mid-point of a transformer secondary which is at zero potential. The filament is heated by a small coil arranged as a secondary to the main transformer primary, Fig. 1. For rectifying both half-waves to the connections may be arranged as in Fig. 2.

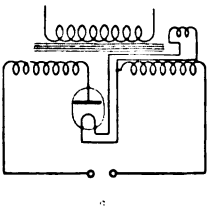

FIG. 1.

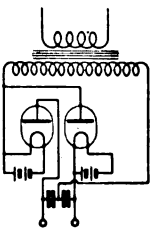

FIG. 2.

There is a corresponding British Application No. 143929, of May 29th, 1920 (Convention date April 9th, 1919), the patent on which has not yet been granted.

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2013. **V. E. Goodwin.** Alternating Current Lightning Arresters. (*General Electric Review*, 23, pp. 429—432, May, 1920.)

Deals with the use of a condenser in series with resistance for protecting electrical machinery from high-frequency surges.

2014. **H. J. Hinks.** The Construction of a Loud Speaker. (*Radiograph*, 3, pp. 38—40, March, 1921.)

Constructional details are given for an instrument utilising an ordinary pattern of Brown's telephone receiver.

2015. **C. W. Hewlett.** A New Tone Generator. (*Physical Review*, 17, pp. 257—258, February, 1921.)

The instrument described can be used as a telephone transmitter, receiver, or loud speaker, or as a standard source of sound. It consists of a thin aluminium diaphragm mounted between two flat pancake coils through which a steady current is passed from a battery to produce the steady polarising field. The coils are connected in series as regards the impressed alternating E.M.F.'s, and in series for the steady battery current.

2016. A New Style of Amplifying Telephone of Simple Construction. (*Scientific American*, 124, p. 13, January 1st, 1921.)

In the apparatus described two powerful horseshoe magnets are employed having an armature mechanically connected to a large mica diaphragm through a magnifying lever. It is claimed that speech can be heard 200 feet from the instrument in the open air, when operated directly by a microphone transmitter without amplifying apparatus.

2017. **W. Schaller.** The Properties of Mica. (*Technical Review*, 9, p. 76, May 3rd, 1921, abstracted from *Cement, Mill and Quarry*, December 5th, 1920.)

2018. **J. G. Frayne.** A High-frequency Resistance Standard. (*Physical Review*, 17, pp. 415—416, March, 1921.)

For high resistances with negligible inductance and capacity "sputtered" quartz fibres are used. Quartz fibres about 10 cm long and about 0·01 mm diameter coated with platinum and immersed in oil were found to meet the requirements. Their skin effect is negligible. Measurements are quoted showing the constancy of the resistances.

2019. **Gesellschaft für drahtlose Telegraphie.** Improvements in Electric Machines. (*German Patent* 298473, October 31st, 1915. Patent granted January 20th, 1920. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 498, June, 1920—Abstract.)

A method of maintaining constant revolution frequency in high-frequency machines by the use of alternating current synchronous motors fed from a source the frequency of which is dependent wholly on the values of a capacity and inductance.

2020. **M. Latour.** Valve Amplifier. (*French Patent* 507308, March 5th, 1919. Published September 10th, 1920. *British Patent* 155254, July 12th, 1920. Convention date March 5th, 1919. Patent not yet accepted.)

The specification describes a method of feeding the filament circuit of a three-electrode amplifier from a power distribution network. The filament is connected to the high voltage mains through a resistance and an inductance. The filament is also shunted by a resistance.

2021. **G. Johannes.** The Kenotron Rectifier. (*Revue Générale de l'Électricité*, 7, pp. 733—746, May 29th, 1920. *Technical Review*, 7, p. 220, November 16th, 1920—Abstract. *Telegraphen- und Fernsprech-Technik*, 9, p. 115, September, 1920—Abstract.)

Continuation of an article published in June, 1919. The limiting factors of current capacity, etc., are discussed, as well as the factors which determine the dimensions of the tube. Various diagrams are reproduced showing the use of one or both half waves also oscillograms to explain the action of the condensers.

2022. **Brown, Boveri & Co.** Rectifier. (*French Patent* 506672, November 27th, 1919. Published August 27th, 1920. *British Patent* 154545, November 26th, 1920. Convention date, November 27th, 1919. Patent not yet accepted.)

According to this patent metallic vapour rectifiers are fed with polyphase currents by employing a combined star and polygon connection of the secondary windings of a three-phase transformer.

2023. **M. Adam.** Alternating Current Rectifiers. (*Radioélectricité*, 1, pp. 553—558, April, 1921; pp. 599—602, May, 1921.)

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2024. **W. Hahnemann** and **H. Hecht.** Theory of Telephone Receiver. (*Annalen der Physik*, 62, pp. 57—84, September 16th, 1920.)

The method is based on replacing the mechanical load by an equivalent electrical load. The effects of losses and magnetic leakage are discussed. The calculated efficiency is checked by means of experiment, and good agreement is found.

2025. **E. F. Huth.** Wireless Receiver. (*German Patent* 316033, August 29th, 1917. Patent granted November 18th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 384, November, 1920—Abstract.)

A receiver in which the telephone receiver coil is divided into two portions, T and T' (see Fig. 3) each half being in series with a detector, the windings and detectors being arranged so as to produce additive effects in the telephones.

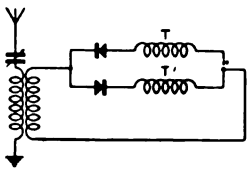

FIG. 3.

2026. **A. H. Lynch.** Ship Line finds Use for Telemegaphone. (*Science and Invention*, 9, p. 48, May, 1921.)

2027. **T. E. Shrader.** Conductivity of Insulating Materials near the Breakdown Voltage. (*Physical Review*, 17, pp. 502—507, April, 1921.)

Test results are given on representative specimens of three classes of insulating materials: (1) those which obey Ohm's law throughout up to the breakdown point; (2) those which obey Ohm's law up to near breakdown followed by an increasing rate of current flow; and (3) those in which the current increases for the whole range of voltage with an accelerating rate up to the breakdown point.

2028. **S. R. Winters.** Tests of Insulating Materials for Radio Use at the Bureau of Standards. (*Radio News*, 2, p. 682, April, 1921.)

A description is given with illustrations of the testing apparatus for insulating materials used at the Bureau of Standards.

2029. **Compagnie Française pour l'Exploitation des Procédés Thomson-Houston.** Continuous Wave Transmitter. (*French Patent* 507995, December 30th, 1919. Published September 28th, 1920.) Also **General Electric Co.** (British Thomson-Houston Co.). (*British Patent* 149409, May 9th, 1919. Patent accepted July 9th, 1920.)

The specification describes a system of continuous wave wireless transmission in which an alternator is employed whose speed is maintained at a predetermined value, whereby the energy is radiated at a constant frequency. The action of keying controls the speed of the driving motor so as to maintain a constant speed of the set, while a resonance circuit is also employed for effecting a further control.

(K.) Aerials (including Earthing Systems, etc.).

(1) AND (2) COMPARISONS OF AERIAL SYSTEMS; ELEVATED AERIALS.

2030. **H. Hoffmann.** The Use of Coils instead of Antennæ as Wireless Receivers. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 31—66, July, 1920.)

A comparison of the advantages of the two methods, followed by a general discussion on the design of coil or frame aerials. Calculations and measurements are given of the inductance and natural frequency of various coils with different types of wire, different pitches, etc. An account is given of five different ways of arranging the receiving apparatus with respect to the coil, some suitable for short and others for long waves. A section is devoted to a study of the errors in direction finding by means of a rotating coil. The concluding section deals with special applications, particularly to submarines. The work was done in the Torpedo Department at Kiel.

2031. **J. E. Stroebel.** The Antenna. (*Q.S.T.*, 4, pp. 5—9, May, 1921.)

A comparison of different antennæ particularly with regard to the arrangements of the leading-in wires. Curves of comparative capacities are given.

2032. **General Electric Co. (U.S.A.)** (British Thomson-Houston Co.). Multiple Aerials. (*British Patent* 142610, March 21st, 1919. Patent accepted July 13th, 1920.)

In connection with multiple aerials—*i.e.*, aerials having several tuned connections to earth disposed along their length—special arrangements are described for grouping the connections to the earth network wires so as to further reduce the resistance of the aerial.

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2033. **W. H. Eccles.** The Capacitance of Flat Top Antennæ. (*Electrician*, 86, p. 72, January 14th, 1921. *Science Abstracts*, 23B, p. 99, Abstract No. 194, February 28th, 1921—Abstract. *Radioélectricité*, 1, pp. 587—588, May, 1921—Abstract. *Revue Générale de l'Électricité*, 9, p. 184 D, June 4th, 1921—Abstract.)

The author refers to a formula recently published by L. W. Austin,* and then gives a simpler one that he has used for some years in designing flat top aerials—viz.:

$$C = cl\sqrt{n-1} \qquad \text{E.S. units.}$$

l = length of flat top; c = capacity per unit length of a single wire of the same gauge and placed at the same height; n = number of wires. c may be written $c = 1/2\log_{\epsilon}(2h/r)$, where h = height and r = radius of the wire.

Examples are given in the paper showing good agreement between calculated and observed values.

2034. **E. Bellini.** Aerial Construction. (*French Patent* 504092, January 28th, 1918. Published June 24th, 1920.)

A receiving aerial for wireless telegraphy or wireless telephony to give the maximum clearness of reception is constituted by two aerials arranged with a right angle between them, the one having the ordinary functions and the other having the greatest possible absorbing power for atmospheric disturbances.

2035. **E. Bennett.** Abstractive and Selective Properties of Radio Antennæ Circuits. (*Journal of the American Institute of Electrical Engineers*, 39, pp. 995—1004, November, 1920; pp. 1052—1062, December, 1920. *Science Abstracts*, 23B, p. 100, Abstract No. 195, February 28th, 1921—Abstract. *Technical Review*, 9, p. 48, April 19th, 1921—Abstract.)

An analytical study of the power abstractive and selective properties of simple antenna circuits, with the object of determining the circuit proportions and frequencies which will make the circuit most highly responsive to the desired signal and least responsive to interference. The main sections dealt with in the article are as follows:—Basis of comparison of receiving circuits; relative response of simple series antenna circuits to detuned C.W. signals; the selective coefficient of a receiving circuit; relations between selective coefficient and the antenna dimensions and operating frequency; relation between selective coefficient and time constant; the calculation of antenna height and area and resonant frequency which will give the highest selective coefficient for a given time constant; feasibility of obtaining tuning inductances with time constants of 0·04 seconds or longer; the maximum power which an antenna can abstract from sustained waves and deliver to a detector; the directive efficiency of a radio system and abstractive factor of an antenna circuit; the combination of frequency with antenna height and area which will lead to a high selective coefficient against strays; effect of the antenna dimensions upon the energy delivered to the detector by an impulse E.M.F.; effect upon the power received of unavoidable departures from the best conditions; conclusions relating to the plain series antenna for receiving purposes.

Curves of transmission efficiencies for various wavelengths and ranges are also included.

2036. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Aerial Construction. (*French Patent* 506989, April 14th, 1919. Published September 2nd, 1920.)

The aerial system comprises a primary aerial supplied by a high frequency source and a plurality of secondary aerials supplied from the primary aerial.

For further particulars see *British Patent* 130064. See RADIO REVIEW Abstract No. 198, February, 1920.

2037. **General Electric Co. (U.S.A.)** (British Thomson-Houston Co.). Wireless Aerials. (*British Patent* 144075, May 26th, 1919. Patent accepted June 10th, 1920.)

Relates to an arrangement of multiple aerials, in which the intermediate grounding connectors along the aerial are connected to capacity counterpoises, instead of to earth.

(3) LOOP OR COIL AERIALS.

2038. **M. Adam.** The Construction of Frame Aerials for Receiving. (*Radioélectricité*, 1, pp. 48—51, June, 1920.)

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* See RADIO REVIEW Abstract No. 466, July, 1920.

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2039. **F. Duroquier.** Radio Direction Finding; the Construction and Utilisation of a Frame Aerial. (*La Nature*, 49(1), Supplement pp. 3—4, January 1st, and pp. 11—12, January 8th, 1921.)

A general outline of direction-finding methods with constructional details for a simple frame aerial, etc.

2040. **E. R. Clarke.** Loop Aerials. (*British Patent* 143580, October 12th, 1917. Patent accepted February 4th, 1920. Published June 24th, 1920.)

For loop aerials for directional radio work the conductor forming the loop may be given a large effective diameter (of the order of 5 feet) by forming it of a number of wires spaced so as to form a cylinder of that diameter. Special arrangements of loops supported by a single mast are also detailed.

2041. The Superlative in Loop Antennæ. (*Scientific American*, 124, p. 29, January 8th, 1921.)

A large loop aerial, measuring 130 feet across, and used in Germany for inter-city wireless communication, is briefly described and illustrated.

2042. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Receiving Apparatus. (*French Patent* 506980, April 10th, 1919. Published September 2nd, 1920.)

The receiving conductor is formed as a coil lying in the vertical plane containing the receiving station and the desired transmitting station. A second coil is placed at right angles to the first-mentioned coil to screen it from undesired waves emitted from an adjacent station.

For further particulars see *British Patent* 129722.*

2043. **E. J. Berg.** A New Coil Antenna. (*Wireless Age*, 8, p. 22, November, 1920.)

A description of the same arrangement as referred to in Abstract No. 43, November, 1919.

2044. **E. F. W. Alexanderson.** A Selective Receiving System. (*Wireless Age*, 8, p. 20, November, 1920.)

The arrangement described is the same as that referred to in Abstract No. 60, November, 1919.

2045. **W. E. Brakes.** A Coil Aerial buried in the Ground. (*Wireless Age*, 8, pp. 17—18. March, 1921.)

Refers to the use of a loop aerial buried in the earth and connected to screened receiving instruments for diminishing atmospheric interference.

2046. **J. Hollingworth.** Loop Aerials. (*British Patent* 149532, September 5th, 1919. Patent accepted August 19th, 1920.)

An aerial which responds to signals from all directions is formed of three or more loops, arranged in more than one plane, consecutive loops being connected in series and wound in opposite directions like the two halves of a figure eight. With a number of such loops the intensity of the received signals is independent of their direction.

(4) TO (12) VARIOUS FORMS OF AERIALS; EARTHING SYSTEMS; MASTS, ETC.

2047. **E. T. Jones.** Jones' System of Underground Reception. (*Experimental Science*, 1, pp. 51—52, August, 1920.)

Contains constructional details for the apparatus for use in conjunction with the aerial system described in RADIO REVIEW Abstract No. 378, May, 1920.

2048. **R. H. G. Matthews.** The Underground Antenna adapted to Amateur Waves. (*Q.S.T.*, 3, pp. 14—16, June, 1920; pp. 18—19, July, 1920.)

2049. **J. J. Honan.** Aeroplane Aerials. (*Wireless World*, 8, pp. 653—656, December 11th, 1920. *Radioélectricité*, 1, p. 113D, April, 1921—Abstract.)

See RADIO REVIEW Abstract No. 90, January, 1920, where the same material has already been dealt with.

2050. **J. H. Rogers.** Aerial Construction. (*French Patent* 506521, November 24th, 1919. Published August 24th, 1920. *L'Électricien*, 52, p. 65, February 1st, 1921.)

The specification describes an aerial for use on submarines. The aerial extends longi-

* See RADIO REVIEW Abstract No. 60, November, 1919.

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tudinally above the submarine, and is insulated therefrom, except at its ends. For further particulars, see *British Patent* 137511.*

2051. A New Design of Aerial Insulator. (RADIO REVIEW, 2, pp. 197—199, April, 1921, and p. 155, March, 1921.)
Describes new insulators designed by C. F. Elwell and Messrs. Bullers, Ltd.

2052. **E. Isherwood.** Electric Earth Plates. (*British Patent* 144376, March 8th, 1919. Patent accepted July 8th, 1920.)
Describes a form of earth connection.

2053. Wooden Masts for Radio. (*Scientific American*, 124, p. 303, April 16th, 1921.)
A short note *re* the advantages of wooden masts, and the stability of those of the Elwell type.

2054. **M. Abraham.** A Law regarding Antenna Models. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 67—70, July, 1920.)
An investigation of the application of the principle of similitude to antenna models. The conclusion reached is as follows: If the model is α times as small in every direction, the model earth must have a conductivity α times as great, for the same dielectric constant. The earth resistances will then be equal, and since being similar the aerial and model have the same radiation resistance, they will have the same decrement.

(L.) Radio Wave Transmission.

(1) GENERAL THEORY.

2055. **J. Brun.** Wireless Telegraphy and the Electrical State of the Atmosphere. (*Radio-électricité*, 1, pp. 241—247, October, 1920. *Génie Civil*, 78, p. 162, February 12th, 1921. *Revue Générale de l'Électricité*, 9, p. 116D, April 9th, 1921—Abstract; p. 158D, May 14th, 1921—Abstract.)
A summary of present knowledge and current theories dealing with wave propagation and with the effect of meteorological factors, and the electrical condition (ionisation, etc.) of the upper atmosphere. The hypotheses of the Heaviside layer are dealt with, as well as Eccles' theory on the effects of ionisation.

2056. **O. Schrieven.** Electromagnetic Waves on Dielectric Wires. (*Annalen der Physik*, 63, pp. 645—673, December 1st, 1920.)
A theoretical discussion of the transmission of waves along wires of dielectric material, followed by a description of an apparatus for the production of such waves by means of a triode and their quantitative investigation by means of a crystal detector. The experiments confirmed the theoretical results.

2057. **R. C. Trench.** Range of Wireless Stations. (*Journal of the Institution of Electrical Engineers*, 59, pp. 157—180, January, 1921.)
The contents of this paper have already been abstracted—RADIO REVIEW, 2, pp. 58—59, February, and p. 169, April, 1921. A full report of the discussion by Professor **G. W. O. Howe**; Major **H. P. T. Lefroy**; Professor **E. W. Marchant**; Professor **C. L. Fortescue**; Mr. **L. B. Turner**; Major **A. C. Fuller**; Dr. **E. H. Rayner**; Dr. **W. H. Eccles**; and Mr. **J. E. Taylor**, is included, together with Captain Trench's reply.

2058. **H. M. Macdonald.** The Transmission of Electric Waves around the Earth's Surface. (*Proceedings of the Royal Society*, 98A, pp. 216—222, December 3rd, 1920; and pp. 409—411, March 3rd, 1921.)
Two mathematical papers dealing with Professor G. N. Watson's discussion of the theory of wave propagation. The second paper deals especially with the conditions for the "steady state" in the case of wave propagation between the surfaces of two concentric conducting spheres.

2059. **J. R. Carson.** Wave Propagation over Parallel Wires: The Proximity Effect. (*Philosophical Magazine*, 41, pp. 607—633, April, 1921.)
A mathematical investigation of the problems of wave propagation over parallel wires in connection with developments of carrier-wave telephony, starting with Maxwell's equations

* See RADIO REVIEW Abstract No. 835, September, 1920.

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and making the simplifying assumption that the exponential propagation factor is a small quantity. The problem is thus reduced to a two-dimensional one.

2060. The Use of the Austin-Cohen Formula for the Solution of some Important Problems in Radio-telegraphic Transmission. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 114—125, August, 1920. *Radioélectricité*, 1, p. 89D, February, 1921—Abstract.)

A Translation from the French (see **Léon Bouthillon**, *Revue Générale de l'Électricité*, 3, pp. 419—425, 1918). Describes a graphical construction for giving the range, best wavelength, etc., in any given case, in accordance with the Austin-Cohen formula.

2061. **G. W. O. Howe.** The Upper Atmosphere and Radiotelegraphy. (*Radio Review*, 1, pp. 381—383, May, 1920.)

2062. **S. Chapman** and **E. A. Milne.** The Composition, Ionisation and Viscosity of the Atmosphere at Great Heights. (*Quarterly Journal of the Royal Meteorological Society*, 46, p. 357, 1920. *Nature*, 105, p. 690, July 29th, 1920—Abstract.)

In this paper read on June 16th, 1920, the authors deal very fully with the present state of knowledge of the upper atmosphere. They conclude that Wegener's geo-coronium does not exist, that the upper atmosphere is free from hydrogen, and that nitrogen is a prominent constituent up to nearly 200 km; above 150 km helium is the principal constituent. The atmosphere changes very greatly at about 100 km and this is the height at which aurora are usually observed. This height and the sharply defined lower surface of auroral displays are consistent with ionisation due to α particles emitted from the sun.

Ionisation may exist at lower levels due to β and γ radiation from the sun; these may penetrate to heights of 50 and 25 km respectively. In all cases the lower surface of the ionised layer would be sharply defined, a point of interest in radiotelegraphy. The question of the persistence of the ionisation and the difference between day and night conditions is not investigated.

(2) Transmission Tests; Ranges; Fading, etc.

2063. The Reception of the Lyons Station in Buenos Aires. (*Radioélectricité*, 1, p. 58, June, 1920.)

Reference is made to the successful reception in Buenos Aires of signals from the Lyons station, which uses not more than 150 kW in the aerial. A frame aerial of only a few decimetres side was used in conjunction with specially selective apparatus.

2064. **L. W. Austin.** The Wave-front Angle in Radiotelegraphy. (*Journal of the Washington Academy of Sciences*, 11, pp. 101—106, March 4th, 1921. *Science Abstracts*, 24B, p. 269, Abstract No. 539, May 31st, 1921—Abstract.)

Experiments are described with a view to actual measurement of the inclination of the wavefront of an incoming signal wave to the vertical at the receiving station. The use of a frame aerial rotatable in two directions at right angles is considered unsatisfactory for this purpose, and a pair of oppositely directed straight wires were mounted upon a wooden frame supported on a mast so that the two wires, which served as aerials, could be rotated together in both the vertical and the horizontal planes. The positions of extinction of the signal were determined, and the line of the wavefront was taken as perpendicular to the wires when in this position. Measurements indicated that for wavelengths over 10,000 metres, the deviation of the wavefront from the vertical under ordinary conditions did not much exceed three degrees. It was also found possible to determine the wavefront inclination of atmospherics, and in some cases to determine a slightly different inclination from that of the incoming signals. In general, however, the atmospherics also had a sensibly vertical wavefront.

2065. The Radio Station at Sandham (Finland). (*Electrician*, 86, p. 390, April 1st, 1921.)

A short note with regard to range tests from this station. It is stated to have been in communication with Poldhu, a distance of 2,300 km.

2066. **J. Kruse.** The Bureau of Standards—A.R.R.L. Tests of Short Wave Radio Signal Fading. (*Q.S.T.*, 4, pp. 6—12, November, 1920, and pp. 13—19, December, 1920. *Telegraph and Telephone Age*, 39, p. 113, March 1st, 1921—Abstract. *Electrical Review*, 88, p. 654, May 20th, 1921—Abstract.)

In conjunction with the Bureau of Standards and the American Radio Relay League test signals were transmitted three nights each week through June and July, 1920, by six amateur

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transmitting stations operating on 250 metres wavelength. Observations of the intensity of the signals were made by fifty recording stations. Frequent checks between curves on adjacent and distant stations were found. No definite connection between weather and transmission was found and occasionally travelling curves appeared successively at various recording stations. Three types of fading were observed, a rapid and very abrupt type occurring mainly in New England, a less rapid and less abrupt type found in all districts covered by the tests and a very slow type of large area which affected all sending stations to the same degree. There was no marked difference in the fading experienced with different types of sending sets, but with spark transmission, a signal that had faded out could often be recovered by re-tuning. This phenomenon was not found with C.W. The tests furnished evidence in support of the belief that such variations are due to varying reflection and refraction of the waves.

2067. Elwell-Poulsen Arcs on Board Ship. (*Electrical Review*, 88, p. 586, May 6th, 1921.)
Reference is made to some long distance communications effected with the Elwell-Poulsen arc installation on board the s.s. *Caronia*. Ranges of 2,800 to 3,500 miles are mentioned and it is stated that the arc was fitted with a special method of keying so that no spacing wave is radiated. The arc was particularly valuable in enabling messages to be got through when atmospherics and other jamming was bad.

2068. Long Distance Work. (*World Wide Wireless*, 2, p. 5, March, 1921.)
Refers to a communication between Eureka radio station and the s.s. *West Camargo* over a range of 1,200 miles in daylight, using a 2 kW 600 metre quenched spark set.

2069. The A.R.R.L. QSS Tests. (*Q.S.T.*, 3, pp. 5—6, June, 1920; pp. 5—8, July, 1920; 4, pp. 5—6, August, 1920.)
Preliminary notes *re* the short wave "fading" tests organised by the Bureau of Standards and the American Radio Relay League.

2070. **S. Kruze.** Station Performance during the Bureau of Standards—A.R.R.L. QSS Tests of June and July, 1920. (*Q.S.T.*, 4, pp. 11—14, September, 1920.)
Tabular results are given of the performance of the recording stations which took part in the Bureau of Standards fading tests.

2071. The Fading Tests. (*Q.S.T.*, 4, pp. 12—14, January, 1921.)
A preliminary report is given in the form of curves of a further series of fading tests carried out for the Bureau of Standards in October, 1920.

2072. Performance of January Q.S.S. Recorders. (*Q.S.T.*, 4, pp. 14—15, May, 1921.)
Some further data with regard to the third Bureau of Standards fading tests.

(M.) Atmospherics (General Articles, Anti-atmospheric Devices, etc.).

2073. Electrical Disturbances due to a Meteor. (*Electrical Review*, 88, p. 554, April 29th, 1921.)
Reference is made to a report from the s.s. *Saxonia* with regard to a large meteor which was seen 15 miles off Halifax. Unusual atmospheric disturbances were reported by wireless operators for a period of twenty-four hours prior to the event, and they ceased after the fall of the meteor.

2074. **L. W. Austin.** Determination of the Direction of Atmospheric Disturbances or Static in Radiotelegraphy. (*Journal of the Franklin Institute*, 171, pp. 617—629, May, 1921.)
In order to study atmospheric disturbances during the months when they are too weak at Washington to be of value for investigation a number of observations were taken on a receiving apparatus set up in various other places. The results obtained at San Juan, Loiza, Cayey, Astora, Bremerton, San Francisco and San Diego are set out in tabular form. It is concluded that: In general static comes from the land rather than from the sea, and that when it appears to come from the sea there is generally land in the given direction at no great distance; that static which increases in a marked degree with the wavelength comes from a great distance while that which varies little with wavelength comes from centres not far away; that Washington afternoon summer static is much more sharply directional than that in the forenoon. In many cases the source of sharply directional static was apparently located in high mountain

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peaks. Two types of static were recognised, one giving a pure shock effect which is heard over a wide range of wavelengths and one which is not heard simultaneously at different wavelengths. The latter has been termed the "spectrum" type since it appears to consist of a large number of independent waves of different lengths. There is some reason to believe that the spectrum type forms a large part of the directive static. The importance of further directional observations is emphasised.

2075. **L. J. B. Verdier.** Eliminating Atmospheric Disturbances. (*French Patent* 498168, January 7th, 1918. Published December 31st, 1919.)

The specification describes a method of eliminating atmospheric disturbances in wireless telegraphy and telephony reception. The method consists in employing an antenna of great capacity and a plurality of successive selecting circuits which eliminate progressively the parasitic currents, so that only the required current is produced in the last circuit. The antenna is arranged to form a circular or polygonal winding.

2076. **International Radio Telegraph Company.** Reducing Interference. (*French Patent* 502782, July 11th, 1919. Published May 26th, 1920.)

For reducing interference from atmospherics two receiving aerials (one or both of which are of the directional type) are employed connected differentially to the receiving instrument, and one of them being so arranged as to give a minimum response to signals from the required direction. Both aerials are affected equally by atmospherics which are consequently balanced out in the receiving instrument. Both radio and audio frequency differential balancing arrangements are shown in different modifications. See also *British Patent* 146997 of July 6th, 1920 (Convention date November 27th, 1916) in the name of **J. L. Hogan.**

2077. **H. J. J. M. de R. de Bellescize.** Reducing Interference. (*French Patent* 504783, October 10th, 1919. Published July 16th, 1920.)

In a wireless telegraphy receiver comprising the usual elements and for receiving musical signals, there are provided two resonators of low and distinct frequency, both operated by the same current rectified by the receiving detector. One of the resonators is tuned to the musical frequency of the signal and the other is out of tune therewith. The resonators act oppositely on a recording apparatus without the interposition of a detector.

2078. **L. Cohen** and **J. O. Mauborgne.** A New Method for the Reception of Radio Signals, eliminating Static and Interference. (*Journal of the Franklin Institute*, 191, pp. 423—424, March, 1921.)

A short abstract of a lecture dealing with the use of "resonance-wave-coils" for radio reception and the elimination of interference.

2079. **Le Matériel Téléphonique.** Reducing Interference. (*French Patent* 505127, November 17th, 1918. Published July 23rd, 1920.)

By combining a plurality of sections having resistance, capacity and no inductance, or resistance, inductance and no capacity, currents of a frequency below a certain value and also currents of a frequency above a certain value, may be eliminated. For further particulars see *British Patent* 135635.*

2080. **H. J. J. M. de R. de Bellescize.** Eliminating Atmospheric Disturbances. (*French Patent* 506142, January 22nd, 1919. Published August 14th, 1920.)

For reducing atmospheric and similar interference the receiving apparatus has two aerials having no mutual reaction. The receiving aerial is tuned to the desired waves and the balancing aerial is slightly mistuned, both aerials having equal damping, inductance, and effective height.

In an example quoted, two closed coil aerials are employed, arranged symmetrically about a central plane but with one coil displaced laterally from the other. Resistances are placed in the leads from the aerials to the coupling coils (which are arranged inside a screened box) so as to equalise the damping of the two circuits. High and low-frequency amplifiers may be employed between the aerials and the differential indicating instrument to which both receivers are connected.

There is a corresponding British application No. 152679 of July 12th, 1920 (Convention date January 22nd, 1919), the patent on which has not yet been granted.

* RADIO REVIEW Abstract No. 523, July, 1920.

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2081. **R. A. Weagant.** Static Preventer buried in the Earth. (*Wireless Age*, 8, p. 18, December, 1920.)

A modification of the double loop static eliminator previously described by Weagant,* in which the receiving station apparatus and the loops are fitted up below ground while a horizontal screening network is stretched over the surface of the earth above the apparatus.

2082. **L. Levy.** Eliminating Atmospheric Disturbances. (*French Patent* 506297, October 1st, 1918. Published August 18th, 1920.)

The specification describes receiving circuits for undamped high-frequency waves with means for eliminating parasitic disturbances.

See also British Specification No. 133306. (RADIO REVIEW Abstract No. 190, February, 1920.)

2083. **H. J. Round.** Wireless Receiving Apparatus. (*British Patent* 149434, May 13th, 1919. Patent accepted August 13th, 1920.)

Relates to electrostatic screening arrangements for the secondary circuit of the receiver and for the valves and other apparatus.

(N.) Interference and Interference Prevention.

2084. **E. F. W. Alexanderson.** Transoceanic Radio Communication. (*General Electric Review*, 23, pp. 794—803, October, 1920. *L'Elettrotecnica*, 7, pp. 458—460, September 5th, 1920—Abstract. *Technical Review*, 7, pp. 322—323, December 7th, 1920—Abstract. *Science Abstracts*, 24B, p. 157, Abstract No. 310, March 31st, 1921—Abstract. *Bulletin de la Société Française des Électriciens*, 10, p. 400, November, 1920—Abstract. *Génie Civil*, 78, p. 491, June 4th, 1921—Abstract.)

The article covers the same general ground as the paper with the same title already abstracted—RADIO REVIEW Abstract No. 1209, December, 1920. The barrage receivers are also described and illustrated.†

2085. **H. J. Round.** Wireless Receiving Apparatus. (*British Patent* 149435, May 13th, 1919. Patent accepted August 13th, 1920.)

For the elimination or reduction of undesired signals it is proposed to use two receiving aerials coupled to the receiving telephones through a phase-changing arrangement. The heterodyne energy for reception is provided by a third auxiliary transmitting aerial. Signals from the direction of this aerial can be balanced out by adjusting the phase of the current from the two receiving aerials.

2086. **Western Electric Company.** Wireless Telephone Apparatus. (*British Patent* 143309, February 18th, 1919. Patent accepted May 18th, 1920.)

In a wireless telephone transmitter distortion arises from the fact that the aerial is tuned to the unmodulated, or carrier, frequency N and is out of tune to the additional frequencies $N + n$ and $N - n$ introduced by the modulation. To overcome this defect, resonant circuits or transformers may be introduced into the low-frequency or modulation circuits to accentuate the intensity of the higher modulating frequencies. For this purpose these circuits may be tuned to frequencies near or above the highest speech frequencies.

Alternatively the compensation for the distortion may be introduced, by similar means, into the low-frequency circuits of the receiver. Secrecy methods of communication become possible if this method is extended to a greater degree.

(O.) Duplex and Multiplex Radio.

2087. **E. F. W. Alexanderson.** Duplex System for Wireless Telegraphy. (*Wireless Age*, 8, pp. 17—18, November, 1920. *Science Abstracts*, 23B, pp. 581—582, Abstract No. 1113, December 30th, 1920—Abstract.)

Description of the same arrangement as that referred to in Abstract No. 64, November, 1919.

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* RADIO REVIEW Abstract No. 18, October, 1919.

† See also RADIO REVIEW Abstract No. 75, December, 1919.

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2088. **Gesellschaft für drahtlose Telegraphie.** Wireless Sending and Receiving Circuit. (*German Patent* 307646, April 10th, 1918. Patent granted January 22nd, 1920. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 147, August, 1920—Abstract.)

A valve circuit (see Fig. 4) with separate aerials for sending (S) and receiving (R). During transmission the coupling coils to telephone and receiving aerial are short-circuited.

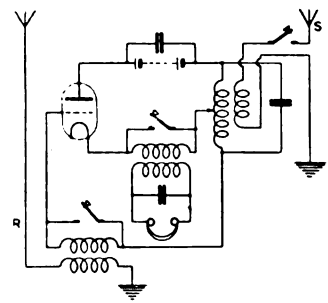

FIG. 4.

(P.) High - frequency Circuits and Measurements.

(1) GENERAL ARTICLES.

2089. **A. Press.** Antenna Form-factor. (*Electrician*, 85, pp. 492—493, October 29th, 1920. *Science Abstracts*, 23B, p. 546, Abstract No. 1035, November 30th, 1920—Abstract. *Revue Générale de l'Électricité*, 9, p. 43D, February 5th, 1921—Abstract. *Technical Review*, 8, p. 190, February 22nd, 1921—Abstract. *Radioélectricité*, 1, p. 81D, January, 1921—Abstract.)

A mathematical discussion of the field at a distant point due to the current distribution in the aerial conductors. The formulæ obtained are not suitable for abstracting but it is shown that there are two form-factors, one magnetic and the other electrostatic, and that together they amply express the relative merits of two dissimilar antenna systems.

2090. **J. St. V. Pletts.** Some Slide Rule Improvements. (*Proceedings of the Physical Society of London*, 33, pp. 57—61, February 15th, 1921. *Technical Review*, 9, p. 112, May 17th, 1921—Abstract.)

The chief features of this new pattern of slide rule have already been described—RADIO REVIEW, 2, pp. 152—153, March, 1921.

2091. **A. Press.** Extension of Heaviside Principle to Operator Functions. (*Electrician*, 86, pp. 349—350, March 25th, 1921.)

Deals with the application of ordinary algebraic methods to mathematical operators.

2092. **H. L. Curtis.** An Integration Method of deriving the Alternating Current Resistance and Inductance of Conductors. (*Bureau of Standards Scientific Paper*, No. 374, April 7th, 1920. *Bulletin of the Bureau of Standards*, pp. 93—124. *Journal of the Franklin Institute*, 198, p. 655, May, 1920—Abstract. *Nature*, 106, p. 641, January 13th, 1921—Abstract. *Bulletin de la Société Belge des Électriciens*, 35, pp. 24—25, January—February, 1921—Abstract. *Science Abstracts*, 24A, p. 138, Abstract No. 306, February 28th, 1921—Abstract. *Physical Review*, 15, pp. 528—531, June, 1920—Abstract.)

The conductor is assumed to be divided into infinitesimal filaments by surfaces which coincide with the lines of current flow and the solution of the problem is then obtained by a process of induction. The formulæ developed correspond exactly with the asymptotic formulæ of Russell. Some experimental results are also quoted.

2093. **A. Russell.** The Capacity Coefficients of Spherical Conductors. (*Proceedings of the Royal Society*, 97, pp. 160—172, April 15th, 1920. *Science Abstracts*, 23A, pp. 287—288, Abstract No. 739, May 31st, 1920—Abstract.)

A mathematical investigation of the electrostatic capacity of spheres, and including approximate formulæ for the capacity between a sphere and a large conductor.

(A.) Radio Stations and Installations.

2094. German Developments in C.W. Stations. (*La T.S.F. Moderne*, 1, pp. 176—180, September, 1920.)

See pp. 370- 372, in this issue for abstract.

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2. Book Review.

THE THERMIONIC VACUUM TUBE AND ITS APPLICATIONS. By H. J. van der Bijl. (New York: *McGraw-Hill Book Co., Inc.* London: *McGraw-Hill Publishing Co., Ltd.* 1921. Pp. 391. 9″ × 6″; with 232 figures. Price 30*s.* net.)

The research work of van der Bijl is known to every student of the thermionic valve. As a research physicist of the Western Electric Company of New York he had unique opportunities for carrying out investigations on the thermionic valve, more especially with regard to its application to telephony. The results of these researches and those of his colleagues are embodied in the book under review. In the preface the author states that he has tried to make the treatment sufficiently elementary "to meet the demands that will necessarily be made on a book of this kind." In our opinion the author has succeeded up to a certain point, but we must confess that we sometimes found difficulty in following the author's reasoning; this was not due so much to the treatment not being sufficiently elementary, as to a lack of sequence in the arguments. We sometimes felt, as we read a sentence over again and wondered just how it followed from the preceding one, that the author, although obviously a master of his subject, could not have had much experience as a teacher. It should be pointed out, however, that the book consists of nearly 400 pages closely packed with facts and arguments with little descriptive matter and an attempt to read it rapidly and in large doses is apt to reduce one's mental alertness.

The book is divided into an introduction and ten chapters. In the introduction the author traces out the history of the subject of thermionic emission and its applications, and then proceeds to explain the plan of the book. The first chapter deals with the properties of electrons, their mass and field when stationary and moving and the relation between space charge and potential distribution. The following two chapters deal with the different methods of producing electrons, with special reference to their emission from heated solids. A clear explanation is given of the modern views on contact E.M.F. and electron affinity. The fourth chapter on the physics of the thermionic valve goes fairly fully into the subject so far as the hard valve is concerned, the effect of gas being treated in the following chapter. Chapter VI. deals with the subject of rectification by means of the two-electrode valve, and also with smoothing devices or filters to give a steady current output. Chapter VII. on the amplifier occupies 120 pages; the subject is treated both mathematically and experimentally. The mathematic treatment is for the most part based on the characteristic equation $I_p = a\left(\frac{E_p}{\mu} + E_g + \epsilon\right)^2$ which is used throughout the book. Various methods are described for the direct experimental determination of the amplification ratio and other constants of the valve.

Chapter VIII. deals with the vacuum tube as an oscillation generator. All the usual methods are considered and questions of phase, wave form and efficiency are discussed. In Chapter IX. we reach the subject of detection which most people regard as the first application of the thermionic valve, as it undoubtedly was historically. Van der Bijl treats modulation and detection together in this chapter. The concluding chapter contains a collection of miscellaneous applications of thermionic tubes including Round's well-known slide-back method of measuring voltages, the ionisation manometer and a brief reference to valves with two grids.

A few misprints are almost unavoidable in a book containing so many symbols with subscripts, but there are two rather unfortunate ones on p. 165, where in equation (15) one of the terms is upside down, and in equation (17) E_p should be E_g. On the whole, however, the book is remarkably free from such blemishes. The book is very well illustrated with diagrams and curves as well as photographs of valves and other apparatus. It would be better if more information were given on the curves so that one might be able to differentiate between them without having to search through the text; sometimes, we must confess, we searched in vain.

Apart from these few criticisms, however, we have no hesitation in commending the book to any one interested in the thermionic valve.

G. W. O. H.

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Books Received.

DIE NEUERE ENTWICKLUNG DER FUNKENTELEGRAPHIE EIN SIEGESZUG DER VAKUUMRÖHRE. By Dr. H. Wigge. (Cöthen-Anhalt: *Verlag der Ingenieur-Zeitung*. Second Edition, 1921. Pp. v + 71, 9½″ × 6¼″, with 59 illustrations. Price not stated.)

MANUAL OF ELECTRICAL UNDERTAKINGS AND DIRECTORY OF OFFICIALS, 1920—1921. Compiled under the direction of E. Garcke, M.I.E.E. (London: *Electrical Press, Ltd.* Vol. XXIV., 1921. Pp. ccxxviii + 1627, 8½″ × 5½″. Price 30*s.* net.)

Correspondence.

MICA CONDENSERS FOR RADIO WORK.

In the March issue of the RADIO REVIEW we published a communication from the Wireless Specialty Apparatus Company with reference to recent litigation against them by the Dubilier Condenser Co. We have received a communication from the latter company pointing out that the statements made are misleading, that the W.S.A. Company have paid $25,000 and the U.S.A. Government $15,000 for licences under the Dubilier Patents, that the W.S.A. Co. have signed, agreed and conceded the priority of all the condenser patents issued to Mr. Dubilier at the time of signing the contract, that up to date the W.S.A. Co. have not obtained one patent on mica condensers and that Mr. Dubilier's latest patent applications are not included in the licence to the W.S.A. Co. The Dubilier Co. support these statements with copies of the contracts, the decision of the U.S. Courts, together with recent letters exchanged between the companies.

As we do not think it desirable to devote further space to this matter, we feel that we are doing justice to both parties in reproducing the above statements before closing the correspondence.—ED.

TRIODE CHARACTERISTICS WITH HIGH GRID POTENTIAL.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In correspondence to the RADIO REVIEW, April, 1921, reference is made in a letter by Dr. B. van der Pol and in an Editorial note to secondary emission effects in three-electrode valves.

Secondary emission from the grid may occur in practice when using valves as oscillation generators. As one example of this, a 200-watt valve directly coupled to an oscillatory circuit was being used as a generator at a frequency of about 500,000 and in an attempt to obtain high efficiency the grid tapping was about three times the anode tapping. Oscillations were obtained satisfactorily, the valve running quite cold, but it was found that a slight increase of the high-tension voltage, which was about 2,000 V, would cause the anode to heat with extreme rapidity.

This phenomenon can be repeated and there is found to be a region of instability where slight changes in any part of the circuit will bring on this sudden heating of the anode.

The valve will be found to remain hard so that the effect is not due to the evolution of gas. A centre zero D.C. milliammeter placed in series with the grid leak indicates that the current changes in direction each time the effect occurs. The explanation appears to be that with the particular adjustment at which this phenomenon occurs the grid and anode voltages at that part of the cycle where the grid is positive, are favourable to a large secondary emission of electrons from the grid. This emission of electrons causes the mean grid current to reverse in direction, to charge the grid condenser to the opposite polarity, thus changing the mean voltage of the grid from negative to positive and enormously increasing the anode current.

A. C. BARTLETT.

Research Laboratories of the General Electric Co., Ltd.,
London, W.
May 20th, 1921.

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THE RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

VOL. II AUGUST, 1921 NO. 8

Editor :
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PHILIP R. COURSEY, B.Sc., F.Inst.P., A.M.I.E.E.

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THE

RADIO REVIEW

VOL. II AUGUST, 1921 NO. 8

Editorial.

A New Direction Finder.—In this issue we publish a description of a new method of direction finding developed by the engineers of the Marconi Company. The advantage claimed for this new method is that it is less seriously affected by the reflection and refraction phenomena which are usually known as night effect. It is now well known that an ordinary direction finder of the single or crossed-coil type may give very erratic results at night and more especially at sunrise and sunset, the direction of the transmitting station appearing to wander about, the deviation in some cases reaching 90° from the true bearing. In the paper published in the February issue of the RADIO REVIEW Mr. T. L. Eckersley showed that one of the main causes of this aberration was the presence of a wave with a horizontal electric field coming down at an angle on to the receiver after reflection from the upper atmosphere. Such effects would therefore be expected when receiving from an inverted "L" aerial, broadside on to the receiving station, since the horizontal portion would radiate waves polarised in the direction to produce these disturbing effects. The system described by Messrs. Wright and Smith consists of the well-known combination of the Bellini-Tosi aerial and an open aerial, adjusted to give a heart-shaped diagram with a single zero. The plain aerial effect which was regarded as an evil by the users of the frame direction finder is here made to serve a useful purpose. The diagrams which accompany the paper show how the polar curve would be distorted by the night effect on certain assumptions. These diagrams indicate, however, that a receiver of this type may give very inaccurate results, since, although the position of the minimum remains unchanged, the shape of the curve on either side of it may be very different. If the signals are so strong that the minimum is sharply defined there should be no difficulty; this agrees with the results given in the paper, the signals from Lyons and Clifden being relatively strong. With weak signals, however, where one would find a wider silence range the correct zero could not be determined so accurately. The fact that experimental results agree with those predicted from these diagrams serves as a further confirmation of Eckersley's theory of the cause of the night effects.

E. H. Armstrong *v.* **Lee de Forest.**—We publish in this issue the judgment delivered by Judge Mayer in the action brought by Armstrong for infringement of his well-known feedback or retroactive receiving circuit.

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It will be seen that this is wholly in favour of the plaintiff. We feel justified in reproducing this judgment almost in full both because of its historical importance and because of its scientific and commercial importance. There is moreover much human interest in Judge Mayer's account of the early struggles of the "enthusiastic never-say-die young student—feed-back Armstrong—with but one thought possessing him." [3004]

The Heart-shaped Polar Diagram and its Behaviour under Night Variations.*

By G. M. WRIGHT and S. B. SMITH,
Marconi Research Department.

The polar curve of a single frame aerial is the well-known cosine diagram and that of a vertical aerial is a circle. If their characteristics be combined in the correct manner a heart-shaped polar curve will be the resultant. To obtain this result the currents induced in a frame aerial and a vertical aerial by an incoming signal must be combined in the correct phase and amplitude. Assuming both to be in tune with the wave frequency, the current in the vertical aerial is in phase with the wave and the current in the frame lags 90° behind the wave. This follows at once from the fact that in the case of an open aerial the E.M.F. induced is proportional to the number of lines cutting the conductor whereas in the case of the frame the E.M.F. is proportional to the rate of change of the number of lines cutting or linking with the frame. Now in order that a perfect minimum may be obtained it is necessary that these two currents shall be in phase, consequently the open aerial current must be made to lag 45° on its E.M.F., and the current in the frame must lead 45°. This shifting of phase is accomplished by a slight mistuning of the two circuits, the vertical aerial being tuned to a little longer wavelength than the signal and the frame a little shorter. It is to be noted that a pure minimum will be obtained by interchanging the mistuning, but the direction of the minimum will be of opposite sense to that previously given.

It will be understood that this adjustment of the phase is necessarily of a very critical character, a very small change of tune producing a large shift of phase in the current in the circuit (providing that the damping is not very large). It is customary in practice to use the Bellini-Tosi system of aerials in preference to a rotating frame, and this complicates the question of phasing still further.

If the aerials are not tuned by variable condensers but are tightly coupled to the search coil of the radiogoniometer then the circuits can be considerably simplified and the critical phasing adjustments eliminated.† This is the so-called "Aperiodic Aerial" method of using the Bellini-Tosi system of

* Received June 14th, 1921.

† See H. J. Round, *Journal of the Institution of Electrical Engineers*, 58, pp. 224—257, March, 1920.

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aerials and is superseding the tuned aerial system. Referring to Fig. 1 a b c is a closed loop aerial which has connected in series with it one field coil of a radiogoniometer L_1; a similar loop is arranged at right angles to it, and is connected to the other field coil of the radiogoniometer. The search coil of the radiogoniometer is connected to the coils L_4 and L_5 in series, and the circuit is tuned by a variable condenser C. L_6 is the jigger secondary coupled to L_5 and is tuned by a variable condenser, the amplifier being connected across its terminals. The vertical aerial A is connected through a resistance R and the coil L_3 to earth. The radiogoniometer is arranged to have as tight a coupling as possible in order that it may act as a transformer and so allow the frame aerial to be effectively tuned by means of the condenser C. The inductance of the field coils should be reasonably large compared with that of the aerials, and the winding of the search coil must nearly fill the space enclosed by the field coils. If the leakage factor is in this way reduced to the lowest possible value, the maximum aerial tuning effect by the condenser C is obtained when the leakage inductance of L_1 L_2 is equal to the inductance of the aerial.

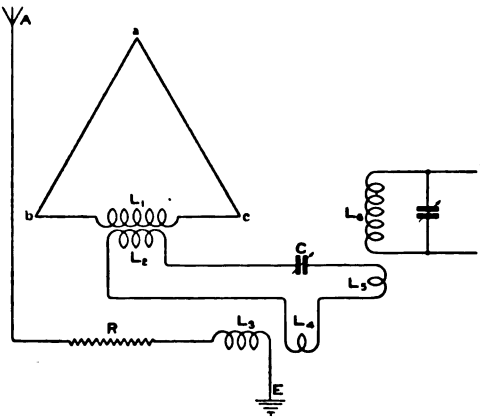

FIG. 1.

The coil L_4 is provided for the introduction of the E.M.F. due to the vertical aerial A.

Now assuming the coupling between L_3 and L_4 and the value of the resistance R to have been suitably adjusted, let us consider the state of affairs existing when a signal arrives from the direction of zero reception of the system. In Fig. 2 let the vector E_v represent the direction and magnitude of the E.M.F. induced by the wave in the vertical aerial. Then the E.M.F. induced in the loop will lag 90° behind E_v and can be represented by E_f. If R is sufficiently large compared with the reactance of the open aerial, the current in this circuit will be in phase with E_v. On the other hand, owing to the fact that the impedance of the loop is mainly inductive the current in it will lag 90° behind E_f as shown by the vector I_f. The vectors I_v and I_f are 180° apart in phase and are consequently in the correct positions to give a balance when the amplitude of I_v is right; which condition is secured by the adjustment of the coupling between L_3 and L_4 (Fig. 1) and, within limits, of the resistance R.

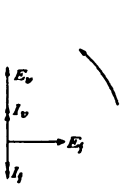

FIG. 2.

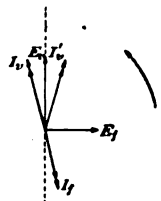

FIG. 3.

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It might, at first sight, be thought that the above reasoning was incorrect owing to the fact that no account has been taken of any shift of current phases in the loop or open aerial circuits by the tuning of the circuit L_2 L_3 L_4 C. But it must be borne in mind that *at the minimum of the heart-shape diagram* (which is the point to which we have referred in the foregoing argument) there is no current in this circuit, and consequently as far as the aerial circuits are concerned L_2 L_3 L_4 C does not exist; therefore, we are perfectly justified in considering the phases, etc., of the currents in the aerials only.

These currents will induce E.M.F.'s in L_4 and L_2 and the condition to be obtained is that the instantaneous E.M.F. in L_4 must be equal and opposite to the E.M.F. in L_2 at all times. This point was brought out experimentally in the first trials of the arrangement. In this case the coil L_4 was not used, but L_3 was coupled on to L_5 and L_6 together. It was found that a slightly different adjustment of L_3 L_2 and C was required to obtain a perfect balance for different couplings between L_5 and L_6. This was due to the fact that the circuits would actually be adjusted so that the current in L_5 produced an equal and opposite E.M.F. in L_6 to that induced by the current in L_3. Under these circumstances the tuning of the circuit L_2 C L_5 would influence the phase of the current in the loop aerial and so upset the balance. It is for this reason that the separate coils L_4 and L_5 are provided for the application of the E.M.F.'s to the circuit L_2 C L_5 L_4.

It is also necessary that the coil L_3 should be of such an inductance that the natural frequency of the open aerial circuit is a little higher than the frequency of the received wave. The reason for this will be seen by a closer study of the vector diagram of E.M.F.'s and currents in the circuits. In Fig. 3 E_v and E_f again represent the E.M.F.'s in the open and closed aerials respectively, being 90° out of phase. Then it is clear that, no matter how large the resistance R is made, the current can never be exactly in phase with E_v but will occupy some phase position such as I_v or I_v' depending upon whether the natural frequency of the circuit is higher or lower than that of the wave. Also since the loop aerial and radiogoniometer field coils possess resistance the current I_f will not lag quite 90° behind E_f. From the figure it can at once be seen that the purest minimum will be obtained when the current in the open aerial occupies the position I_v, that is when the periodic time of that circuit is a little shorter than that of the wave.

The general shape of the polar diagram of the system is shown in Fig. 4, the plane of the frame aerial being along OX. The equation to the curve is $r = R(1 + \sin\theta)$ where $2R$ is the maximum ordinate on the curve. Hence the points of maximum slope occur at p and q. A good method of employing the combination as a direction finder having only one minimum is to connect a reversing switch in the search coil of the radiogoniometer. The pointer is then adjusted until no change of strength occurs upon throwing over the switch. Directions taken in this manner must always be treated with suspicion

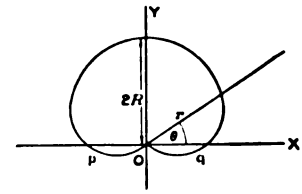

FIG. 4.

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during the night, as we shall see later that the bearings obtained are subject to " night effect."

In adjusting the coupling with the vertical aerial it is to be noted that if the E.M.F. induced by the coil L_3 (Fig. 1) is too large a bad minimum is obtained, if on the other hand this E.M.F. is too small two minima appear as shown in Fig. 5. At the correct coupling only one minimum results, which minimum is the direction (+ 0° or + 180°) of the sending station.

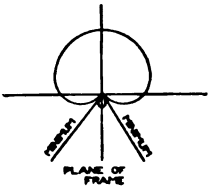

FIG. 5.

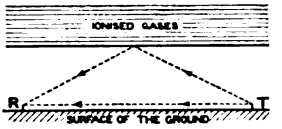

FIG. 6.

NIGHT VARIATIONS.

The discussion which follows is based upon the theory of night variations proposed by T. L. Eckersley, which theory receives very strong support by observations of the behaviour of the heart-shape diagram during periods of violent night effects on the ordinary direction finder.

During the day time the atmosphere becomes more or less ionised under the action of ultra-violet light emitted from the sun. This ionisation extends from the surface of the ground to the highest layers of the upper air. As soon as the sun sets and the ultra-violet rays are withdrawn the ions formed during the day commence to recombine, and since the rate of recombination is proportional to the pressure the ionisation disappears very rapidly near to the earth and very slowly at great heights. The net result of this process is that during the night a more or less sharp dividing line exists between the un-ionised and ionised portions of the atmosphere as shown in Fig. 6. Estimates as to the height of the dividing line vary from 30 miles to 100 miles or more. An ionised gas behaves much in the same way as a partial conductor towards an electric wave. It will refract or reflect the ray, the reflecting power depending upon the angle of incidence of the ray. During the night, therefore, a wave has two alternative paths from the sending to the receiving stations—(1) directly from one station to the other along a great circle on the earth's surface, and (2) by one or more reflections from the ionised layer, the path of this layer still lying approximately in the plane of the same great circle. Owing to the fact that the direct ray travels over the conducting surface of the earth it must arrive at the receiving station polarised at such an angle that the magnetic force is parallel to and the electric force is perpendicular to the ground, both of course being at right angles to the direction of propagation of the wave. A ray of this type will in future be termed " normally " polarised. On the other hand, in the case of the indirect ray which arrives at the receiving

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station after reflection from the ionised layer, there is no such natural limitation to the angle of polarisation, and the ray may travel with magnetic force horizontal or vertical or any intermediate angle. Of course this presupposes that the indirect ray from the transmitter is either emitted with an abnormal polarisation or is abnormally polarised by some kind of reflection or refraction.*

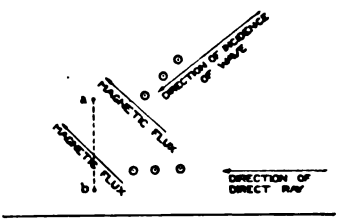

FIG. 7.

When a normally polarised ray impinges on a vertical frame, arranged so that its plane is perpendicular to the direction of propagation of the wave, no E.M.F. is induced in the loop because there is no linkage of the flux in the wave with the closed aerial, also it is to be noted that such a ray will never produce an E.M.F. no matter what its vertical angle of incidence may be. Consequently if the plane of the frame be turned at right angles to the direction of the transmitting station, no E.M.F. will be induced in it by either the direct or reflected rays of Fig. 6 so long as they are normally polarised. But there is no particular reason why the indirect ray should be so polarised, and if the magnetic flux has a component in the vertical plane of the ray, *i.e.*, at right angles to the normally polarised component, then an E.M.F. may be induced in the frame. This is shown in Fig. 7 where ab is the frame turned so that its plane is perpendicular to the direction of the direct ray. The arrow heads ⊙ show the direction of the magnetic flux in this ray. The direction of the indirect ray is shown as coming down at a vertical angle on to the frame and the arrows indicate the component of the flux in the vertical plane. It is obvious that this flux is linked with the frame, and so induces an E.M.F. in it.

It is convenient therefore to split the field of the reflected ray up into two components; namely, one horizontally polarised and the other vertically. The difference between the true direction of the transmitting station and the observed direction is dependent upon :--

(1) The intensity and phase of the reflected ray.
(2) Its angle of polarisation.
(3) The vertical angle of incidence.

We are now in a position to study the effects upon a loop aerial under various conditions. In Fig. 8 curve A represents the reception due to the direct ray, curve B is that due to the normally polarised component of the reflected ray. It is to be noted that the phase relationship between these curves can vary through 180°, so their relative amplitudes will vary considerably. During the day time only A can exist, unless the transmitter be a nearby aeroplane. While during night time B may under certain conditions become comparable with A. The third curve C is due to the other

* See T. L. Eckersley, RADIO REVIEW, 2, pp. 231—248, May, 1921.

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component of the reflected ray and from a study of Fig. 7 it is obvious that it should be at right angles to the curves A and B. Curves B and C need not necessarily be in phase, for instance, they may be due to separate reflections.

We have shown that during the day time conditions only curve A can exist, therefore the observed direction of the transmitting station will be at right angles to the plane of the frame. Let us now consider the simple case when B and C are 180° out of phase with A, then as soon as the reflected ray is received B and C of Fig. 8 will appear. As B increases in amplitude the resultant of A and B will diminish with the result that component C will become more effective in the determination of directions. The result will be a rotation in the direction of the arrow, finally when the resultant of A and B is zero the frame will have rotated through 90° and its plane will be in the direction of the transmitting station. At this point it should be observed that the frame is unaffected by the resultant of all the components of the wave particularly the vertically polarised component. This will be referred to later when considering the heart-shaped polar curve. (Any further rotation of the frame will cause a reversal of the sign of the component C.) If B now increases in amplitude still further the frame will again receive and a rotation still in the direction of the arrow will be observed, until finally the observed direction will have rotated through 180°. If on the other hand B decreases in amplitude the rotation will be in the opposite direction to that indicated and the direction will consequently have rotated back through 90°. Both of these effects can often be observed during periods of violent night effect. From the foregoing reasoning it can be seen that the deviation from true bearing of a transmitting station can vary between the limits $\pm$ 90°.

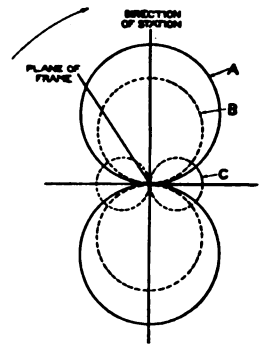

FIG. 8.

Now the heart-shaped polar curve is the result of combining the E.M.F.'s induced in a vertical aerial and a frame and in this case the minimum of signals is obtained when the effects of the frame and open aerial are equal and opposite. Thus if we so arrange matters that the E.M.F. induced in an intermediate circuit by the current in the open aerial is just equal to (and in phase with) that induced by the current in the frame when at its position of maximum reception we obtain the ordinary heart-shaped diagram having one minimum. It should be observed that the direction of zero reception of a normally polarised ray lies in the plane of the frame, and from the remarks on the previous page it will be clear that a minimum reception for an abnormally polarised ray will also exist in the same direction. (The curve C of Fig. 8 being at the minimum.) The purity of the minimum in the case of the reflected ray will depend upon the vertical angle of incidence of the ray. If the vertical angle of incidence is steep the receiving power of the vertical aerial to the normally polarised component of the reflected ray

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will be reduced, whilst the linkage with the frame will remain constant and consequently the minimum will become impure, in fact there will be two minima their angular displacement being governed by the difference in amplitude between the frame and vertical reception due to this ray. There is reason to believe that the reflected ray is always arriving at a fairly small inclination and therefore the minimum should always remain nearly pure.

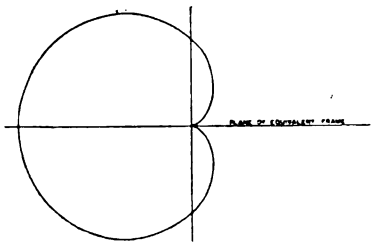

FIG. 9.—Heart-shaped diagram with no reflected ray (day time).

In Figs. 9 to 13 are shown the types of heart-shape polar diagrams obtained under the influence of night effect.

Fig. 9 is the ordinary diagram of a frame and vertical aerial with no indirect ray. Fig. 10 illustrates the effect of an indirect ray in phase with the direct ray and of such an intensity as to give a night effect of 30° on the frame alone. It will be noted that there are two minima, one in the same position as the

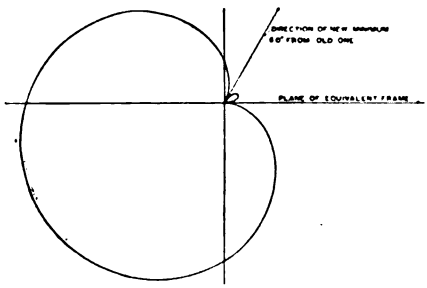

FIG. 10.—Reflected ray in phase with direct ray.

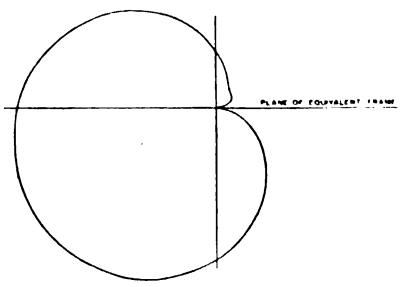

FIG. 11.—30° out of phase.

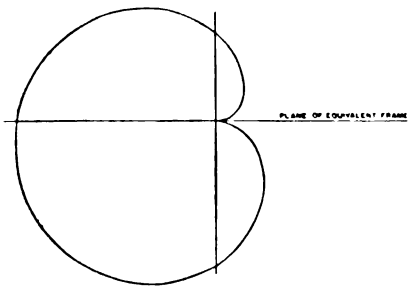

FIG. 12.—60° out of phase.

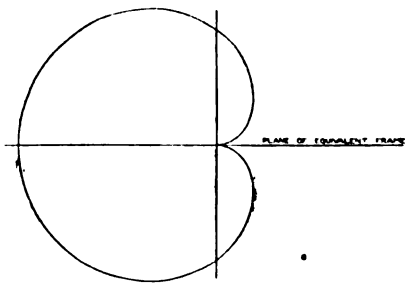

FIG. 13.—90° out of phase.

FIGS. 10, 11, 12, and 13.—Heart-shaped diagrams with night variations. In each case balance adjusted on direct ray in day time, and reflected ray = 0·577 of the intensity of the direct ray.

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normal minimum of Fig. 9 and a second one 60° away from it. This development of two minima is characteristic of the behaviour of the diagram whenever the reflected ray is in phase with the direct ray.

Fig. 11 is the diagram when the indirect ray is 30° out of phase with the direct ray. In this case the second minimum has become impure and is filling up.

Fig. 12 shows the case of 60° phase difference between the rays. There is now a decided flattening remaining on the side of the diagram where the second minimum existed.

Fig. 13 shows the case when there is a phase difference of 90° and now the curve is symmetrical on both sides of the minimum and comparison with Fig. 9 will show, however, that the minimum is much sharper than when no reflected ray existed.

The important point to notice is that theoretically the direction of zero signals of Fig. 9 remains unchanged throughout all variations of phase and intensity of the reflected ray.

If a series of resulting polar curves of a simple frame are constructed for various night effects, it will be noticed that there are broadly two classes of polar curve obtained namely :—

(1) Minima well defined but quite incorrect.
(2) Minima ill defined, and almost impossible to obtain a direction.

Both types are very commonly met with in practice and upon such occasions ample proof of the stability of the heart-shaped polar curve can be obtained. The second type is very prevalent and upon such occasions the general shape of the polar curve is very similar to that shown in Fig. 13.

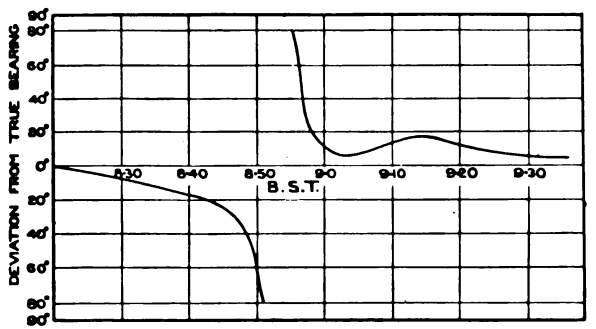

FIG. 14.—Variation of bearings on Bellini-Tosi Direction Finder. Lyons arc sending. Sunset, August 7th, 1920.

(NOTE.—B.S.T. = British Summer Time, one hour ahead of Greenwich Mean Time.)

A large number of variations upon Figs. 9 to 13 at once suggest themselves ; the cases chosen are only very simple illustrations, and in these cases the A and C rays are only being received, C being vertically polarised.

Owing to the large fading in signal strength at sunset and sunrise it appeared quite reasonable to make observations at such times. Observa-

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tions on the Lyons arc transmitter were made at Chelmsford during the early summer of 1920, using the Bellini-Tosi direction finder and a heart-shaped polar curve. The difference in bearing of the marking and spacing waves of Lyons often differed by 45° also the minima on one wave would be sharp while the other would be very ill defined. The varying polarisation and phase relations of the direct and reflected rays could often be heard taking place, and quite frequently the sharp minima would become blunt and *vice versâ*. At sunset these variations are often very rapid and consequently it is very difficult to obtain a continuous record of the variations. Fig. 14 shows the deviation from true bearing of the Lyons signal during a sunset period. It is to be observed that the bearings rotated through 180°, at 8.53 p.m., B.S.T.,* and for a few seconds the polar curve of the frame was

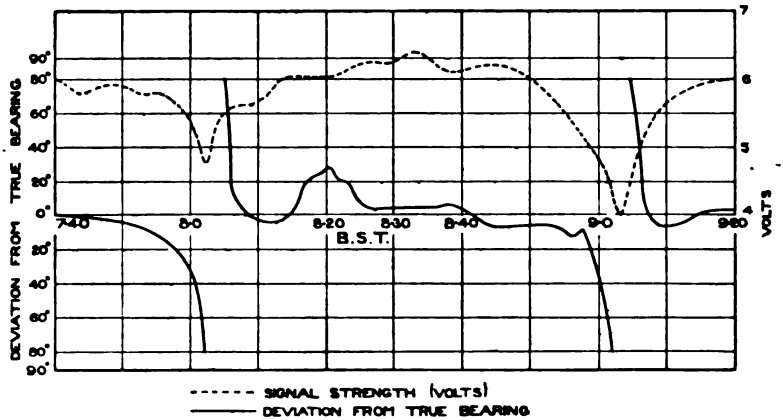

FIG. 15.—Signal strengths and variation of bearings on Bellini-Tosi Direction Finder. Clifden transmitting on 6,000 metres C.W., September 28th, 1920. Sunset at Clifden = 7.25 p.m. B.S.T.* Sunset at Chelmsford = 6.38 p.m. B.S.T.*

practically a circle. At the same time the heart-shape curve was very much after the form of Fig. 13. During the whole of this series of observations the minimum of the heart-shape curve remained correct but of course considerable changes in the shape of the curve each side of the minimum were recorded. At the point of maximum night effect a very large change in signal strength was recorded, probably the direct ray and the normal component of the reflected ray were of equal amplitude and opposite phase, so that the only remaining signal will be that due to the vertically polarised component.

In September a new series of observations on the Clifden valve transmitter were made, and a qualitative record of the signal strength was made on a vertical aerial and the night effect observed upon a direction finder and a heart-shaped polar curve. The variations were extremely marked

* B.S.T. = British Summer Time, one hour ahead of Greenwich Mean Time (G.M.T.).

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during the early part of this month, but as winter approached they became much less. In fact during the latter part of October only minor changes in bearings and signal strength were observed.

In Fig. 15 is shown the deviation from true bearing plotted with the variation of signal strength. Normally at sunset there is only one period of violent variation, that shown in Fig. 14 being quite typical, but of course the maximum effects are not always recorded, very often the deviation only varies $\pm$ 20°. On some occasions the bearings will remain high in a positive direction and no negative variations are recorded probably due to the extremely variable nature of the whole phenomena. It is very interesting to note that at the point of maximum night effect (Fig. 15) the signal strength undergoes a very marked reduction.

During a long series of observations on the Clifden transmitter the minimum of the heart-shape polar curve has always been constant, this fact seems to prove that the angle of incidence of the reflected ray is always small otherwise this minimum would become impure, also that the angle of the plane of the ray is vertical.

The most important points to note are as follows:—

The minimum of the heart-shaped diagram always gives the true bearing of the transmitting station and is therefore an aid in direction finding when night variations are known to be prevalent.

Owing to the above-mentioned fact the system is of great utility when the minimum is employed to obtain a balance for duplex purposes, the day time balance remaining constant during periods of night effect.

A High-frequency Machine of Greater Specific Power and Higher Efficiency.*

By MARIUS LATOUR.

In recent years, the chief problem connected with the production of high-frequency currents by dynamo-electrical machinery has been the possibility of obtaining frequencies of the high order required. With that end in view, different types of machines have been devised, several of which have interested the author and he has described them in a previous publication.†

The technique of high-frequency machines has already evolved considerably, and it is appropriate to discriminate between the different types of machines from the point of view of weight per kilowatt and efficiency.

After a thorough investigation and while awaiting the more precise data which should be forthcoming from the manufacturers shortly, it would appear, from the above standpoint, that the machine marketed by the Société Française Radio-Electrique (see my *American Patent* No. 1234914 and my *British Patent* No. 107193) which I have designated under the

* Received June 22nd, 1920.

† See Latour, *Proceedings of the Institute of Radio Engineers*, 8, pp. 220–237, June, 1920; RADIO REVIEW, 1, p. 491, July, 1920, and Abstract No. 781, September, 1920.

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name of "homopolar machine with partial utilisation of the periphery" or "homopolar machine with a reduced number of stator slots," is deserving of the highest merit.

May I be permitted to recall here that the losses in iron at high frequencies are calculable beforehand with precision in comparative designs, using the formulæ already published by the author.*

Allotting the symbols:

$2a$ = thickness of laminations,

μ = permeability,

ρ = resistivity,

τ = hysteretic angle,

$B_{app.}$ = apparent flux in the laminations,

$\frac{2\pi}{\omega}$ = frequency of the magnetic field,

and putting $m = \sqrt{\frac{2\pi\mu\omega}{\rho}}$, $\alpha = \sqrt{1 + \sin\tau}$, and $\beta = \sqrt{1 - \sin\tau}$, the total losses W are expressed by the following formula:

$$W = \frac{\omega^2 a}{4m\rho} \cdot \frac{\alpha \sinh 2m\alpha a - \beta \sin 2m\beta a}{\cosh 2m\alpha a - \cos 2m\beta a} B^2_{app.}$$

The hysteretic angle τ of very thin laminations can easily be determined by using a reactance coil, the closed core of which is made up of these laminations, and measuring the power factor $\cos\phi$ of the coil when it is being energised by a low-frequency current (50 cycles). Under those conditions there remain only the losses by hysteresis, and we have $\sin\tau = \cos\phi$. In fact, the angle of hysteresis of very thin laminations is greater than that of ordinary laminations.

Fig. 1 represents the curves corresponding to the observed total losses (heavy line) and the computed total losses (dotted line) in the case of silicon laminations 0·07 mm thick, for frequencies of 17,000 and 30,000. It will be noted that these curves very nearly coincide. This holds good for frequencies and qualities of laminations within wide limits of variation.

Thus, with the formula quoted, it is possible to predetermine the electrical efficiency of an alternator.

The laminations of recent manufacture are far superior to those of previous make, and there is reason to hope for still further improvement in the near future.

If, however, we confine ourselves to the laminations at present available and which conform to the following constants: $2a = 0{\cdot}05$ mm, $\rho = 30$ microhms/cm, $\sin\tau = 0{\cdot}4$, it is possible to construct an alternator type S.F.R., of 200 kW, at 20,000 cycles, having an efficiency proper of 80 per

* See, for instance, *Proceedings of the Institute of Radio Engineers*, 8, pp. 220—237, June, 1920; RADIO REVIEW, 1, p. 491, July, 1920, and Abstract No. 781, September, 1920.

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cent., including all electrical and mechanical losses.* It is doubtful if this efficiency can be obtained elsewhere.

The second type of machine suggested, namely, the homopolar machine with variable reluctance (see my *American Patent* No. 1330638), cannot,

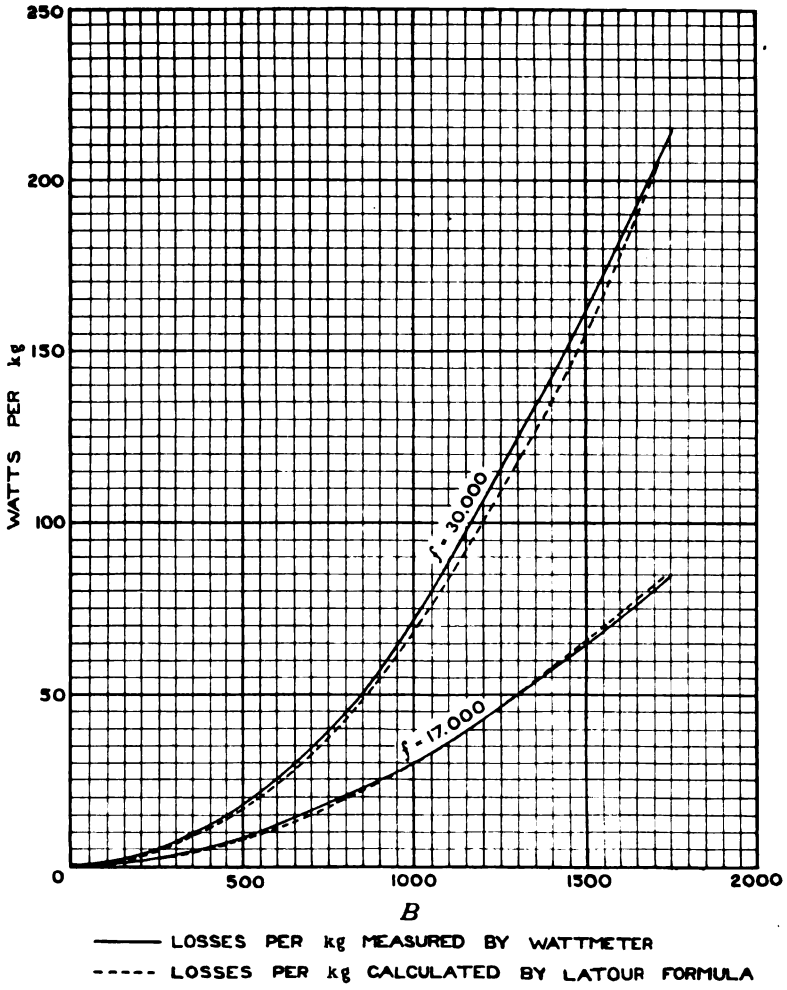

FIG. 1.—Losses in silicon sheet $\frac{1}{100}$ths mm thick.

without modification, attain an equal efficiency. This particular type of machine is represented in Fig. 2 for a two-coil model which has been tested

* This efficiency is already practically reached in the alternator at Coltano which is made up of laminations of a lower grade than those now available.

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for 30,000 cycles. Fig. 3 indicates the coupling of the two coils with the exciting circuit and the antenna. As a matter of fact, the "dampers" or metallic masses inserted between the bundles of laminations and shown

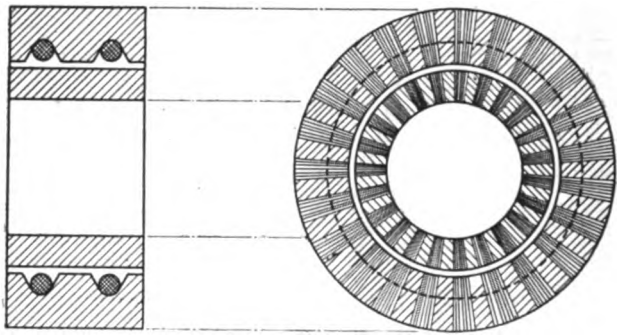

FIG. 2.

in the cross-section perpendicular to the shaft, Fig. 2, are far from providing sufficient shielding from side leakage fluxes which emanate from the walls of the bundles of laminations perpendicularly to the plane of the laminations, at least for spacings of 2 mm, at 30,000 cycles corresponding to the relatively low peripheral speed of 150 metres per second. Under those conditions, it is impossible to realise a greater efficiency without resorting to a different type of construction.

This very peculiar type of machine, which, by the particular arrangement of its circular winding, can produce directly any desired frequency, might undoubtedly have had a real success some years ago, but it cannot to-day compete with the homopolar machine with reduced number of stator slots, already on the market.

Leaving aside the fairly complicated Goldschmidt machine the efficiency of which is unquestionably lower, it remains to be decided if the homopolar machine with reduced number of stator slots is finally superior to the ordinary homopolar machine which is a real industrial possibility at 20,000 cycles. It is well known that the Alexanderson machine is but a particular form of this ordinary machine.

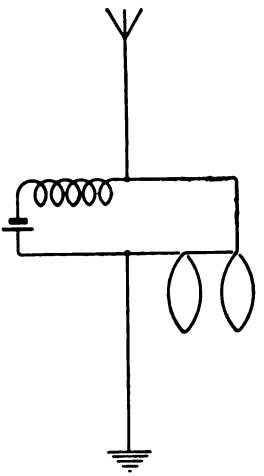

FIG. 3.

Figs. 4 and 5 exhibit in their natural sizes the outline of the opposite teeth of an ordinary homopolar, also for a homopolar machine in which the number of slots on the stator has been reduced to one-third. Both machines are designed to furnish 20,000 cycles at equal peripheral speeds, namely, 150 metres per second.

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In both cases the slots are of equal depth. The proportion between the width of the teeth and the slots is also the same in both cases, the teeth having, at their narrowest point, a width equal to half that of the slots.

Under such conditions, if we admit of an equal value for the alternating induction in the iron of the teeth of both machines, *i.e.*, the same variation in the steady flux which permeates the teeth, the three coils in series in Fig. 4 would enclose the same variable flux as the single coil of Fig. 5 and would therefore give exactly the same E.M.F. as the single coil of Fig. 5. Hence, to obtain the same output in both cases, the slots would have to allow the passage of the same current. One readily notices that, even without making allowance for the greater space taken up by the insulation in the machine of Fig. 4, the copper losses would be exactly nine times greater than those in the case of Fig. 5. In fact, the cross-section of the conductor in Fig. 4 is three times smaller and the length of the circuit three times as long as that in Fig. 5. Taking into account the space taken up by the insulation, which in the case of Fig. 4 is necessarily three times that in Fig. 5, it is safe to assume that the copper losses in the machine of Fig. 4 would be fifteen to eighteen times as great as those in the case of Fig. 5 for equal outputs. If we also take into account the inadmissible local heating up which would ensue, it is easily seen that the machine of Fig. 4 could not give the output of that in Fig. 5 when keeping up the same flux variation.

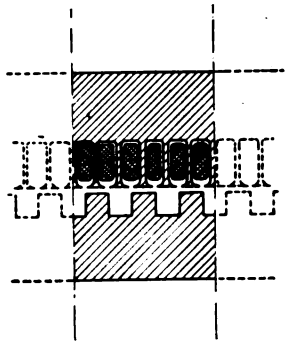

FIG. 4.

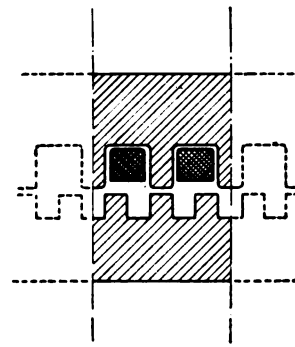

FIG. 5.

In practice, it would be necessary to boost the flux variation through the teeth to a much higher value in the case of Fig. 4 than in the case of Fig. 5, and the current through the slots would be thereby decreased, but the iron losses would simultaneously increase.

At all events, the total losses in the stator will be appreciably greater in the case of Fig. 4 than in the case of Fig. 5. It does not appear that, even with a powerful artificial cooling, it would be possible to draw the same maximum power per centimetre of armature width in the case of the machine of Fig. 4 as in the machine of Fig. 5.

However, in so far as the iron losses in the rotor are concerned, the ordinary

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machine is more advantageous. In fact, in the machine of Fig. 4, the rotor teeth are subjected to negligible flux variations, while those in the machine of Fig. 5 alternately face an open stator slot and a tooth, and they therefore undergo appreciable flux variations at a frequency of 20,000/3 which entails important losses. But figures show that this increase in losses is considerably lower in practice than the increase in stator losses in the ordinary homopolar machine. It is immediately seen that as soon as the quality of laminations improves, these rotor losses will decrease, and that the machine of Fig. 5 will score over that of Fig. 4.

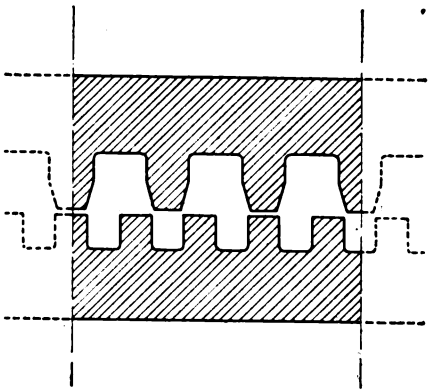

FIG. 6.

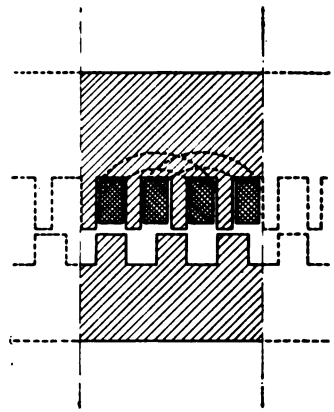

FIG. 7.

It is to be noted that in the case of the machine with reduced number of slots, it is possible to minimise the iron losses in the stator by not utilising entirely the available space for the copper, and by increasing the cross-section of the teeth at the bottom of the slots in such a manner as to decrease the magnetic induction. This leads to an outline of "meshing" teeth.* Fig. 6 shows the outline of the teeth of a machine for 500 kW at 15,000 cycles having a peripheral speed of 150 metres per second. One may reckon on an efficiency approximating 85 per cent.

The author has thought of obtaining an intermediate solution between the type of machine of Fig. 5 and the ordinary machine, by resorting to a two-phase machine whose tooth outline is shown in Fig. 7 (see *German Patent* No. L—50841 now granted).

According to the author, the two phases are connected in parallel to the antenna with series capacities

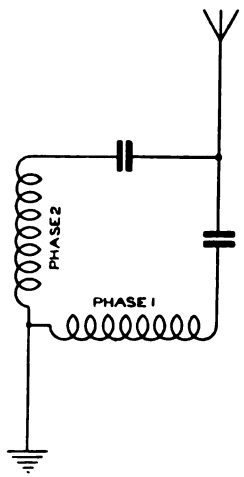

FIG. 8.

* This outline has been suggested by Mr. Belfils of the Société Alsacienne de Constructions Mécaniques.

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of different values as shown in Fig. 8, so as to re-establish a coincidence of phases and thus transform the two-phase output of the machine into single-phase output in the antenna as formerly suggested by Bethenod.

Again, it would be possible to use directly the two phases of this machine for directional radiotelegraphy, using two antennæ separated by a quarter of a wavelength such as had been anticipated by the author and suggested independently by Professor Howe.

This two-phase machine, the idea of which aimed at a reduction of the iron losses, and which is very tempting from a theoretical point of view, reveals itself, after rather minute computations, somewhat inferior in efficiency to the machine of Fig. 5. Its superiority would only become apparent at greater peripheral speeds, such as 200 metres per second.

It therefore appears that the specific power and efficiency of the machines shown in Figs. 5 and 6, are really remarkable.

Lastly, a very interesting advantage of the S.F.R. machine from the practical standpoint, is that from the fact that we are working with weaker flux variations in the stator, the number of parallel circuits in the machine for a given terminal P.D., is lower.

Radio Telephone Circuits and Modulation.*

By W. A. MACDONALD.

In the design of continuous wave signalling apparatus, especially of units not greater than 10 kilowatts output it is generally recognised that the three-electrode valve presents greater advantages than other known means.

During the past few years much interest has been manifested in the application of the three-electrode valve to radio telephone communication and consequently numerous circuits and methods of modulation have been devised, a few of the more desirable of which will be discussed in the following paragraphs.

Three general methods of controlling high frequency oscillations in accordance with speech frequencies have been used, with varying degrees of success, namely, (A) antenna absorption; (B) grid control; and (C) plate control.

In the absorption method probably the first means of varying the amplitude of the high frequency oscillations was by inserting a microphone directly in the antenna circuit, or shunting it around a portion of the antenna loading inductance. This method, however, proved entirely impracticable except for very small powers because of the difficulty in the design of a microphone sufficiently heavy to handle

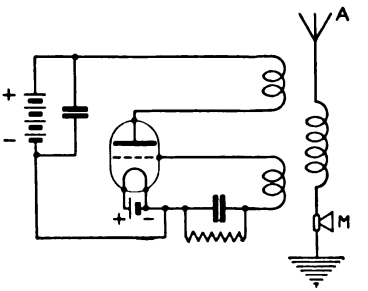

FIG. 1.

* Received December, 1920.

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large currents (Fig. 1). Another method which is more applicable to higher powers is to have the antenna current absorbed by an appropriate number of three-element valves, and dissipated in the valves in the form of heat (Fig. 2).

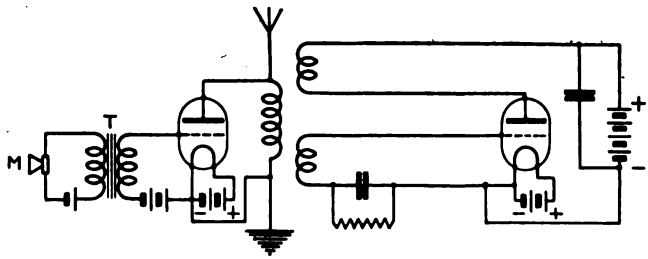

FIG. 2.

Grid modulation has been used to some small extent, but never with any very great success, due principally to the poor efficiency at which the circuits could be operated, and still obtain good modulation. Modulation in this manner can be accomplished by inserting a microphone and speech transformer in the grid circuit of a three element valve (Fig. 3).

When speech is impressed on the microphone M the grid is thrown either positive or negative with respect to its former value, by means of the speech transformer T, which varies the direct current load on the plate circuit, and consequently the alternating component or antenna current.

The circuit generally associated with plate control is that known as the constant-current system, in which one or more valves are used as oscillators and an appropriate number as modulators (Fig. 4). In this system the total plate current is supplied through a large choke coil L, both oscillators and modulators being adjusted to take equal current. When the grid voltage of the modulator tube is varied by means of the microphone M and speech transformer T the resistance varies between infinity and almost zero, making available for the oscillator, twice the voltage, when the resistance of the modulator is infinity and practically nothing when the resistance falls to almost zero. This system of modulation depends entirely on the presence and character of the choke L in the circuit. If this choke coil is properly designed and has a high impedance compared to the impedance of the tube for voice frequencies it is obvious that the total load to the plates

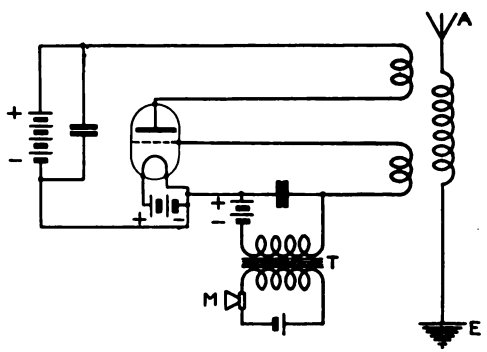

FIG. 3.

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will remain constant regardless of the change in the resistance of the modulator tube. Hence a modulated wave of varying amplitude will be radiated varying between zero and twice the average. This is only true, however, when the tube has ample electron emission from the filament.

Numerous methods of modulation study have been used, the most common

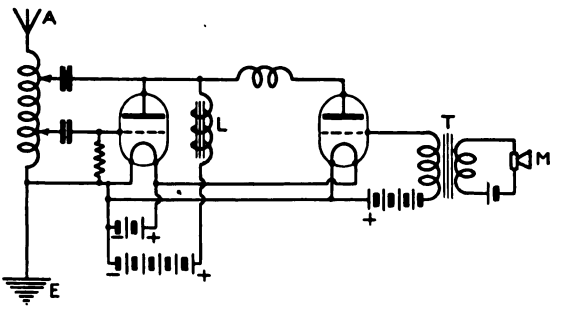

FIG. 4.

being that of observing the amplitude of the direct current plate supply to the oscillator and modulator on an oscillograph. This method may be considered as entirely satisfactory where it is known that the output is proportional to the input. In the following experimental work, however, as a large variety of circuits and tubes were used, it was considered that there would be less chance for error to occur if a low impedance rectifier suitably coupled to the antenna and connected to an oscillograph were used (Fig. 5).

As a number of complete telephone sets were available it was considered that it would be of value to determine what order of modulation to expect. The first set and circuit studied was one using plate current control and known as the constant-current plate method of modulation. The complete set is used by the U.S. Signal Corps—U.S. Army—and is known as the S.C.R. 67.

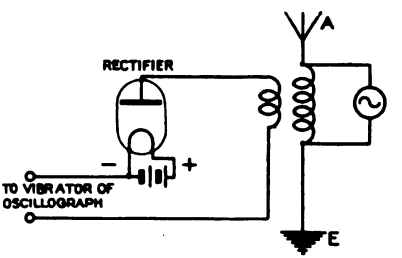

FIG. 5.

This employs two type VT–2 transmitting tubes (oxide coated platinum filaments) one being used as an oscillator and the other as a modulator. The complete unit is rated at about 5 watts high frequency output.

Fig. 6 represents an oscillogram of the rectified antenna current for the vowels Ō and E. Referring to the oscillograph line A is the zero line of the oscillograph, line B the average value of unmodulated high frequency current, and line A′ and B′ the peak values of modulated speech. In this particular case the average value of antenna current was 0·6 amperes. As the deflection

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of the oscillograph is proportional to the antenna current, it is apparent that a modulated wave is radiated varying about 80 per cent. above and below the average value.

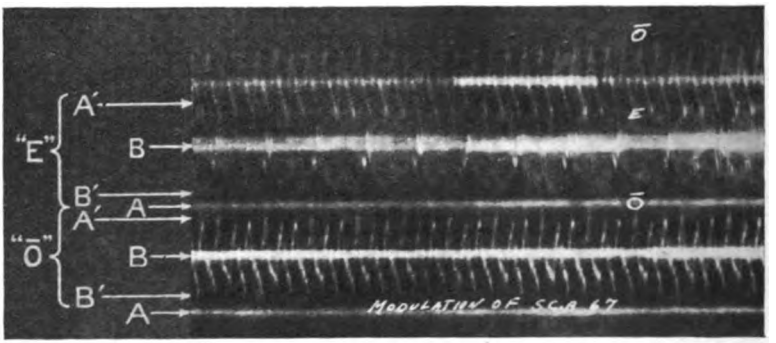

FIG. 6.—Modulation of S.C.R. 67. (From A to B = 0·6 ampere.)

This amount of modulation varies of course with different tones of the voice and in some cases is much less than that shown. Although in this case it was necessary to talk considerably above the average tone to obtain this amount of modulation, generally speaking between 80 and 90 per cent. modulation while talking in the ordinary conversational tone seems to be the most desirable. This allows sufficient margin so that even when speaking above the average tone of voice the modulated wave will never quite decrease to zero.

Fig. 7 shows an oscillogram for practically the same type of circuit as

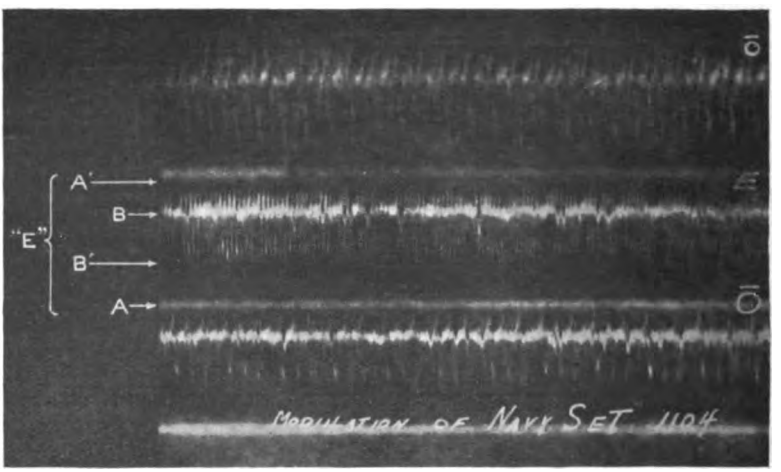

FIG. 7.—Modulation of U.S. Navy Radiotelephone Set. (From A to B = 0·9 ampere.)

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previously shown except that type VT–14 (tungsten filament) tubes were used.

It will be noted in this case that the modulation is only slightly above the average output and about 50 per cent. downward. This may be caused by

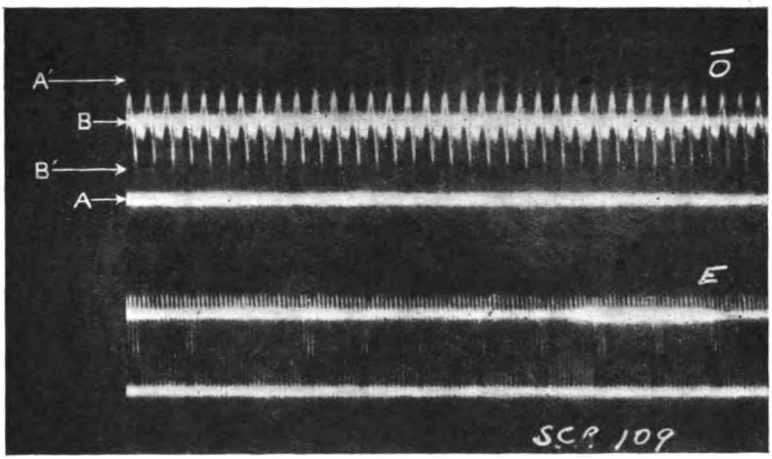

FIG. 8.—Modulation of S.C.R. 109.

a poorly designed choke coil in the plate circuit, but points more directly to the fact that with a given filament current the tube has reached saturation, and the electron emission is not sufficient to take care of the additional load of the modulator during speech.

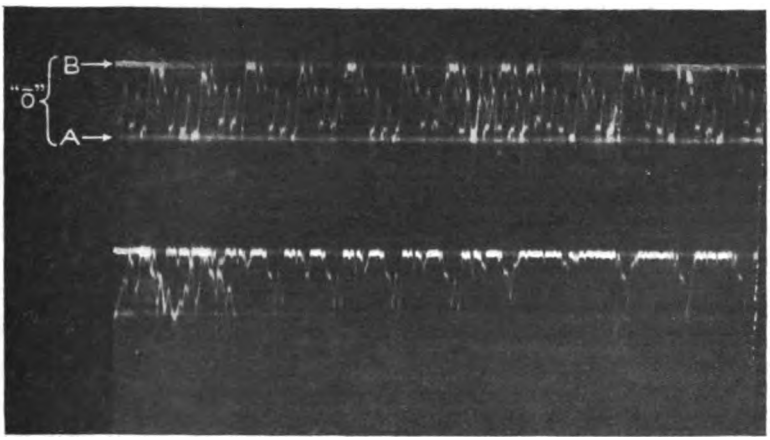

FIG. 9.—Modulation of 1 kW de Forest Radiotelephone Set. (Modulation by absorption method.)

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Fig. 8 shows another oscillogram of practically the same circuit with the exception that two 50 watt (tungsten filament) tubes were used, and in addition a speech amplifier, to amplify the voltage impressed on the grid of the modulator from the microphone and speech transformer. As in Fig. 7 the modulation does not go very much above the average value although in one case it is driven to zero. This further bears out the theory that while operating the tube at its maximum output it has practically reached saturation. The fact of its being driven to zero is directly due to the speech amplifier which amplifies the voltage impressed on the grid of the modulator sufficiently, so that for the downward half of the cycle the resistance of the modulator tube is practically zero.

Fig. 9 represents an oscillogram of a telephone set manufactured by the De Forest Telephone Company, and rated as a 1 kilowatt unit.

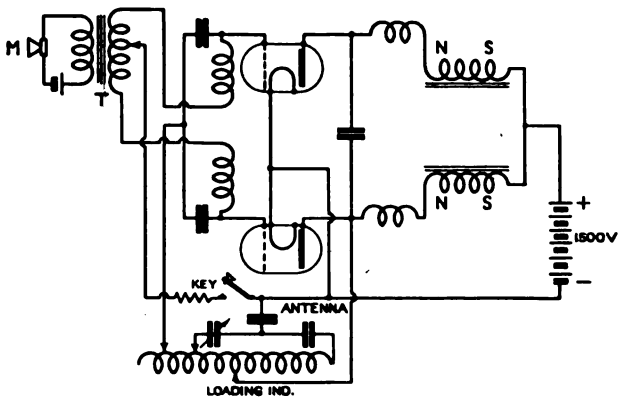

FIG. 10.—Circuit of de Forest 1 kW Radiotelephone Set.

Referring to the oscillogram (Fig. 9) and the circuit diagram (Fig. 10), it can be readily seen that this is purely an absorption method of modulation, where the efficiency is so low at the best adjustment for telephone operation that it would be practically prohibitive.

Summing up the results so far obtained it is readily seen that Fig. 6 represents the most desirable form of modulation. That is, using the constant current method of modulation in connection with a tube of ample electron emission.

Theoretically if this circuit is properly designed it should radiate a modulated wave varying between zero and twice the average value, or for peak values give twice the current or four times the power.

In the design of practically all classes of continuous wave transmitting apparatus, considerable trouble has been encountered in the past, in changes in the frequency while transmitting. It is a well-known fact that in continuous wave telegraphy where the signal is received by virtue of the difference in frequency between the incoming signal and a local heterodyne that any

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slight changes in the oscillating circuit of the transmitter will cause perceptible changes in the received frequency, in many cases causing total loss of signal. This is of course less pronounced in radiotelephony or buzzer modulated telegraphy but it is still a very objectionable feature.

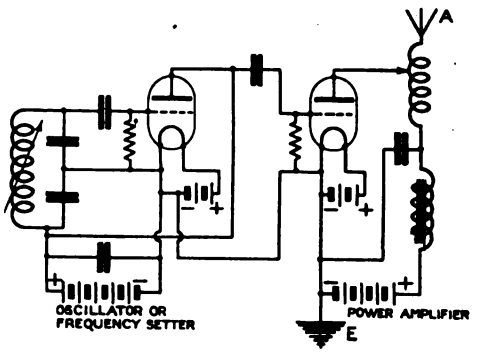

FIG. 11.

The need for absolutely constant frequency apparatus on the smaller installations, such as ships, airplanes, dirigibles, etc., is apparent when it is considered that the antenna is continually swaying back and forth causing changes in frequency as great as 20,000 cycles in 500,000.

A form of constant frequency circuit used with considerable success by the U.S. Signal Corps, in France is known as a power amplifier (Fig. 11). This circuit employs one three element valve as an oscillator, the output of which is impressed on the grid of one or more amplifying valves and suitably coupled to the antenna. Any changes now occurring in the antenna circuit will only tend to slightly reduce the antenna current, the frequency being previously determined by the fixed oscillating circuit.

Using then as a working basis a power amplifier and combining with it the most desirable method of modulation, as previously shown (Fig. 6), a circuit is obtained as shown in Fig. 12.

A circuit of this character was set up under laboratory conditions, using as a master oscillator and modulator two VT–2 valves, the output of which was amplified by two 50 watt valves in parallel. (Western Electric type G tubes.)

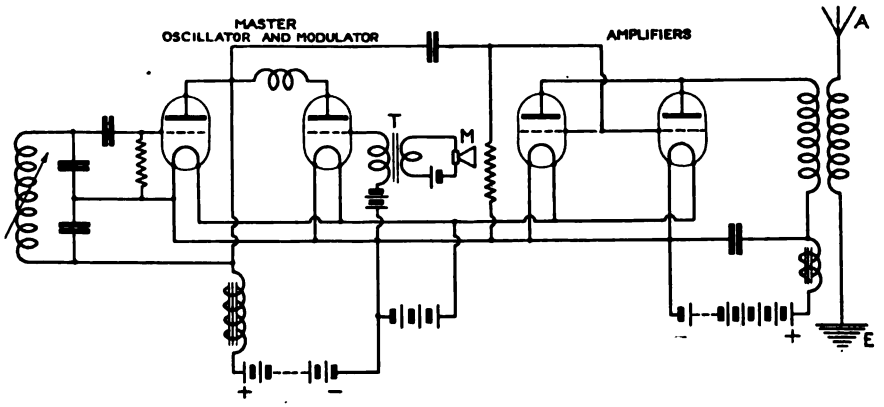

FIG. 12.

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A circuit of this character was used on the U.S.S. *George Washington*. Two type P pliotrons were used as master oscillator and modulator, the output of which was amplified by twelve type P pliotrons. Thirty-two amperes was obtained in the antenna. Fig. 13 shows the modulation obtained with this form of circuit.

In this case the average antenna output was 3·5 amperes or 120 watts. For peak values of modulated current, where approximately 30 per cent. increase in current was obtained, the current was 4·55 amperes or 207 watts. This then makes available for the antenna a current of amplitude varying between zero and 4·55 amperes for peak values. As can be observed from the oscillogram the bottom of the modulated wave is more or less distorted, and is not symmetrical above and below the average antenna value. From

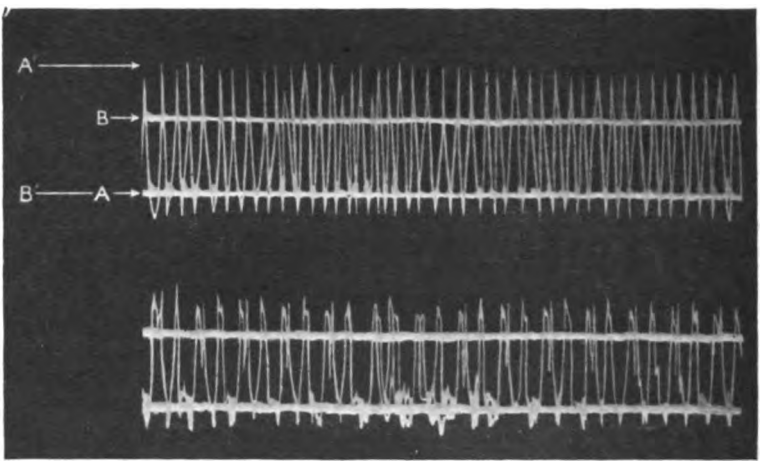

FIG. 13.—Modulation of Radiotelephone using Power Amplifier.

observation of the oscillogram it would seem then that the speech was more or less distorted. This was proved experimentally by listening to the speech at a distance of thirty-five miles. Although the speech could be readily understood, considerable distortion was apparent, especially on the letters of higher frequency.

Although this form of circuit more nearly approaches constant frequency than any of the others previously discussed, it can hardly be considered as constant frequency in the true sense of the word.

Let us consider the action in the master source of supply before being amplified. For convenience consider an oscillator and modulator as represented by two resistances in parallel which are being supplied by current through a common choke coil (Fig. 14). Assuming now that by some means the resistance of R_2 is for an instant of time reduced to practically zero. If the total supply is through the choke L and this choke presents a sufficiently

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high impedance at the frequency at which the resistance is being varied, the total input to the two resistances will remain practically constant. For an instant of time then the resistance R_2 takes all the energy in the circuit. In the reverse manner, of course, when the resistance of R_2 is made very great the energy is then made available for R_1.

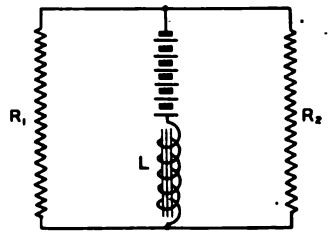

FIG. 14.

Applying this now to the case of the oscillator and modulator, the oscillator being considered as R_1, a voltage varying in amplitude in accordance with speech frequencies will be impressed on the plate. It is obvious then that with this change in load on the plate circuit both the impedance and capacity of the tube will change, causing changes in frequency. Any such changes arising in the master source of supply will naturally be amplified and transferred to the antenna in a corresponding degree.

A circuit which more nearly meets the requirements of absolutely constant frequency is that shown in Fig. 15. For this purpose a master oscillator or frequency setter is used which supplies an exciting potential to the grid of a suitable amplifier. Modulation can be accomplished by any of the known means, preferably plate modulation.

Any changes in the constants of the amplifier, modulator, or antenna systems will not affect the transmitted frequency, as the exciting frequency is of constant value and the amplifier can be considered as a one way device which cannot react on the source of supply.

Fig. 16 represents an oscillogram of the speech obtained from the circuit as shown in Fig. 15, Fig. 17 represents the modulation obtained from the same circuit but with the addition of a speech amplifier.

The laboratory arrangement used employed four tubes, two Western

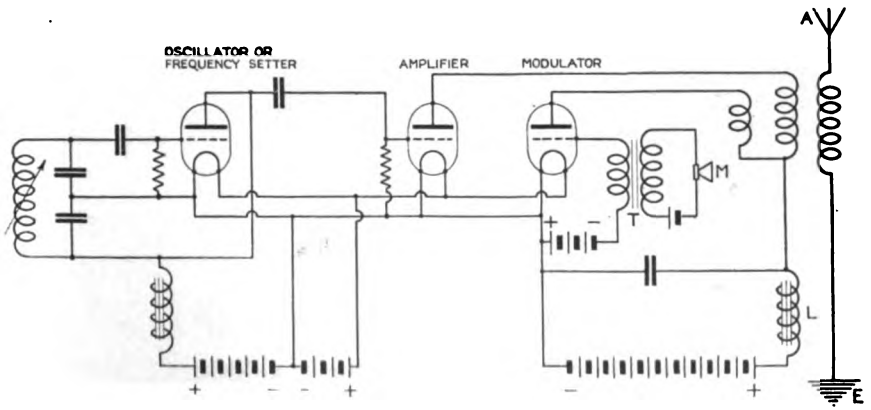

FIG. 15.

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Electric 50 watt tubes for the amplifier, and modulator, and two VT–2 tubes for master oscillator and speech amplifier. By using this circuit in preference to that shown in Fig. 12 a greater total output is obtained with an equal

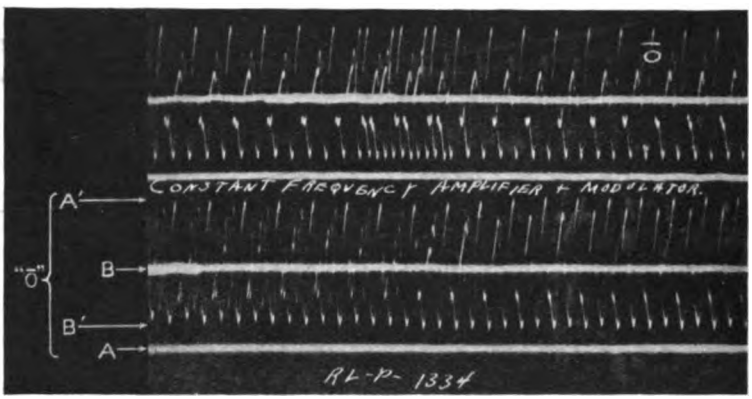

FIG. 16.—Modulation of Set using constant frequency Oscillator and Modulator.

number of tubes. For example: the average antenna current was 2·5 amperes (62·5 watts). For peak values twice the current or 5 amperes (250 watts) is obtained. This makes available for the antenna a current varying in amplitude between zero and 5 amperes. Comparing this with the values obtained in the previous circuit, 43 watts is actually gained.

Even more desirable than the small saving in efficiency is the smooth symmetrical form of the modulated wave, which is practically free from distortion.

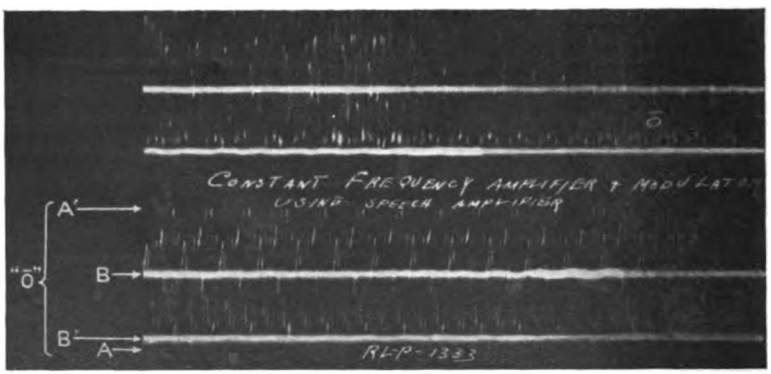

FIG. 17.—Modulation of Set using constant frequency Oscillator and Modulator with Speech Amplifier.

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Based on the above experimental data, together with a great number of field tests, results indicate that suitable modulation of an *amplified* high frequency carrier wave give not only more efficient operation but a much superior quality of speech.

On the Function of the Variable Anode Tap Connection in Triode Generators.*

By E. V. APPLETON, M.A., M.Sc.

It was discovered during the war that the output current of a triode generator can very often be increased by a careful adjustment of the point at which the anode is connected to the aerial tuning inductance. Thus in the well-known circuit of Fig. 1 there is one position of the anode contact K along the coil $L_1 + L_2$ which gives maximum oscillatory current. This note deals with the theoretical significance of this optimum position.

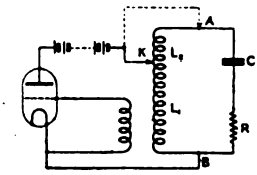

FIG. 1.

It will be seen from the figure that although the whole of the inductance $L_1 + L_2$ is used in the oscillatory circuit only a portion of it (*i.e.*, L_1) is included in the anode circuit. We shall call this latter portion the anode circuit inductance. Our problem thus resolves itself into determining the relation between L_1 and the other electrical constants of the circuit to give optimum oscillatory current.

The problem is best approached by considering first the simpler case in which the anode contact is made at A instead of at K. The oscillatory circuit may then be regarded as equivalent to a non-reactive resistance of value $\frac{L}{CR}$ for alternating currents of its natural frequency. (In this case $L = L_1 + L_2$.)† We may thus regard the total anode circuit resistance as being equal to $\rho + \frac{L}{CR}$ where ρ is the mean internal resistance of the triode.

Let us assume that during an oscillation the maximum grid voltage reached is v_g. The anode current changes produced may be regarded as being due to an electromotive force gv_g acting in a circuit of resistance $\rho + \frac{L}{CR}$ where g is the voltage amplification factor of the tube. The anode

* Received January 21st, 1921.

† [If L_1 and L_2 have mutual inductance, see equation (4).—ED.]

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current i_A will then be given by $\frac{gv_g}{\rho + \frac{L}{CR}}$ where the symbols of the variables all refer to maximum values. Now the ratio of the oscillatory current J in the circuit LC to the anode current i_A in such a case is known to be $\frac{L\omega}{R}$ where $\omega^2 = \frac{1}{LC}$. We thus have

$$J = \frac{L\omega}{R} \cdot i_A = \frac{gv_g}{\rho + \frac{L}{CR}} \cdot \frac{L\omega}{R} = \frac{gv_g L\omega}{R\rho + L^2\omega^2} \quad . \quad . \quad . \quad . \quad (1)$$

This last quantity is a maximum when $L\omega = \sqrt{R\rho}$, that is, when $L/C = R\rho$. It thus appears that for all wavelengths a definite ratio of inductance to capacity gives maximum oscillatory current for a given antenna resistance. But in most transmitters in which a range of wavelengths is used it is impossible to keep to such a ratio as the aerial capacity is usually fixed. Thus for long wavelengths, when L is of necessity made large, the condition mentioned above is no longer maintained resulting in a small value of J. By the use of the anode tap connection K it is possible to bring about the increase of wavelength by an increase of self-inductance, at the same time keeping the ratio of the anode circuit inductance to capacity such as to produce optimum oscillatory current.

To make the alterations from the simple case outlined above to the case in which the contact is at K we require to find

(*a*) The equivalent resistance of the oscillatory circuit from K to B.
(*b*) The ratio of the oscillatory current J to the anode current i_A.

The oscillatory circuit and connections are represented diagrammatically in Fig. 2 where i_1 and i_2 are the currents through L_1 and C respectively; i_A is the anode current, and v_A the potential difference between points K and B. From Kirchhoff's equations we have

$$i_A = i_1 + i_2$$

$$i_1 = \frac{v_A}{j\omega L_1}$$

$$i_2 = \frac{v_A}{R + j\omega\left(L_2 - \frac{1}{\omega^2 C}\right)}.$$

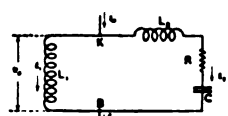

FIG. 2.

Eliminating i_1 and i_2 we have

$$\frac{i_A}{v_A} = \frac{R + j\omega L_1 + j\omega\left(L_2 - \frac{1}{\omega^2 C}\right)}{Rj\omega L_1 - \omega^2 L_1\left(L_2 - \frac{1}{\omega^2 C}\right)}$$

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that is, since $L_1\omega >> R$

$$\frac{i_A}{v_A} = \frac{R}{-\omega^2 L_1\left(L_2 - \frac{1}{\omega^2 C}\right)} = \frac{R}{L_1^2\omega^2}$$

Thus the equivalent resistance of the oscillatory circuit to alternating current of its natural frequency is $\frac{L_1^2}{CR(L_1+L_2)}$. (*Cf.* $\frac{L}{CR}$ when $L_2 = 0$.) Therefore in the case where the anode connection K is used the total anode circuit resistance is given by $\rho + \frac{L_1^2}{CR(L_1+L_2)}$. Thus for a grid voltage change of maximum value v_g we have

$$i_A = \frac{gv_g}{\rho + \frac{L_1^2}{CR(L_1+L_2)}} \quad \ldots\ldots\ldots (2)$$

The relation between the oscillatory current J and the anode current i_A may be obtained from considerations of the energy supplied to the oscillatory circuit. Thus we have

$$i_A^2 R' = J^2 R$$

where R' is the equivalent resistance of the oscillatory circuit.

Substituting for i_A from (2) we have

$$J^2 = \frac{R'}{R} \cdot \left\{\frac{gv_g}{\rho + \frac{L_1^2}{CR(L_1+L_2)}}\right\}^2$$

and

$$J = gv_g \cdot \frac{L_1\omega}{R\rho + L_1^2\omega^2}$$

The value of J is found to be a maximum when

$$L_1\omega = \sqrt{R\rho} \quad \ldots\ldots\ldots\ldots (3)$$

In a practical case where L_1 and L_2 are portions of a single coil the mutual inductance M between these portions may be considerable. If this is taken into account it may be shown in the same way that maximum oscillatory current is obtained when

$$(L_1 + M)^2 = \frac{R\rho}{\omega^2} \quad \ldots\ldots\ldots (4)$$

A further note as to the meaning attached to ρ (the mean internal resistance) is necessary. It is a well-known experimental fact that maximum oscillatory current is obtained when the anode current with the valve not oscillating is equal to half the saturation value (i_s). In such a case the mean anode circuit resistance would be written approximately as $\frac{2v_0}{i_s}$ where v_0 is the voltage of

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the anode battery. The final formula for optimum conditions may therefore be written

$$L_1 + M = \frac{1}{\omega}\sqrt{\frac{2v_0R}{i_s}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

When the coil of which L_1 and L_2 are parts consists of a single layer the determination of the inductance $L_1 + M$ is a simple matter if Nagaoka's factors are used. Thus in a coil of total length l and inductance L, comprising two portions of length l_1 and l_2, of self-inductances L_1 and L_2 and mutual inductance M, we have

$$L = L_1 + L_2 + 2M$$

or $$\pi^2d^2n^2l\kappa\left(\frac{d}{l}\right) = \pi^2d^2n^2l_1\kappa\left(\frac{d}{l_1}\right) + \pi^2d^2n^2l_2\kappa\left(\frac{d}{l_2}\right) + 2M$$

where d is the diameter of the coil, n the number of turns per unit length and $\kappa\left(\frac{d}{l}\right)$, $\kappa\left(\frac{d}{l_1}\right)$ and $\kappa\left(\frac{d}{l_2}\right)$ are Nagaoka's factors.

Thus $$L_1 + M = \frac{\pi^2d^2n^2}{2}\left\{l\kappa\left(\frac{d}{l}\right) - l_2\kappa\left(\frac{d}{l_2}\right) + l_1\kappa\left(\frac{d}{l_1}\right)\right\}.$$

On testing this for typical examples it is found that $L_1 + M$ is approximately directly proportional to l_1. Thus as an approximate formula for optimum conditions we have

$$f \doteqdot \sqrt{\frac{2v_0RC}{i_sL}}$$

where f represents the fraction of the length of the aerial tuning coil included in the anode circuit.

The amplitude of the oscillation reached in a case in which the anode contact is made at K (see Fig. 1) will now be considered.

The usual method of arriving at the conditions for infinitesimal oscillations is to find the differential equation representing the relation between one variable electrical magnitude of the oscillatory circuit (*e.g.*, voltage across the condenser or inductance) and time. This equation can usually be written in the form

$$\frac{d^2v_a}{dt^2} + 2\kappa\frac{dv_a}{dt} + \omega^2v_a = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where κ and ω are functions of the slopes of the voltage-current characteristics of the tube. These slopes may only be considered constant for small changes of v_a. Thus for infinitesimal oscillations κ must be zero, ω being for practical purposes the angular frequency of the oscillation. Proceeding in this way we may show for the above circuit that for κ to be zero we must have

$$M' = -\frac{\kappa_2L_1 + \frac{L_2 + L_1}{L_1}CR}{\kappa_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

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where $\kappa_1 = \frac{\partial i_a}{\partial v_g}$, $\kappa_2 = \frac{\partial i_a}{\partial v_a}$ and M' is the mutual inductance between $L_1 + L_2$ and L_3.

But this limiting condition does not represent the case of a tube producing vigorous oscillations in which case M' is numerically greater than the value demanded by (7). For such a practical case the question of stability becomes of importance. If we restrict the symbol v_a as before to the variable part of the anode voltage we have $v_g = -\frac{M}{L_1} v_a$, a relation which holds for all values of the current through L. Thus it is immediately possible to draw on the characteristic diagram an "oscillation characteristic" which represents all values of the anode current for which the above-mentioned relation is fulfilled. The conditions during an oscillation are then represented by a point which oscillates on this curve.

During an oscillation the representative point in travelling to and fro on the oscillation characteristic will reach regions where the limiting conditions obtain, *e.g.*, at points A and B in Fig. 3.

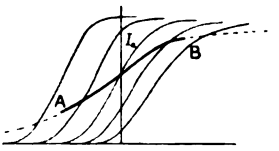

FIG. 3.

For positions of the representative point between these two limits the triode and its connections act as a negative resistance across the oscillatory circuit. For positions of the representative point beyond these limits (shown dotted in diagram) this shunt resistance becomes positive and tends to increase the damping of the oscillatory circuit.

It might at first be thought that the oscillation is maintained at the limiting points A and B but this cannot be the case as energy cannot be supplied to the oscillatory circuit indefinitely. We might put the matter in another way and write equation (6) as

$$\frac{d^2 v_a}{dt^2} + \left\{ \phi(|v_a|) - A \right\} \frac{dv_a}{dt} + \omega^2 v_a = 0$$

where A is constant in which case 2κ is negative for small values of $|v_a|$ but becomes zero when $\phi(|v_a|)$ equals A. Assuming some function for $\phi(|v_a|)$ is tantamount to assuming some equation for the static characteristics. Thus if we use the empirical relation used by van der Bijl ($i_a = A'(v_0 + v_a + g v_g)^2$) it may be shown that in a symmetrical case the maximum voltage reached is $\frac{3\pi}{4}$ times the voltage required to bring the representative point to a portion of the characteristic surface where the limiting condition just obtains. Of course no importance must be attached to the exact value of the constant $\frac{3\pi}{4}$. The important thing in connection with the present method of considering the problem is that it should be shown to be greater than unity.

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In the case of an unsymmetrical oscillation characteristic such as is almost always found in practice it is difficult to find a suitable mathematical expression to represent the curve. The following method may then be used. It depends on the assumption that the output current is practically sinusoidal. We have already seen that an oscillatory voltage $v_a \sin \omega t$ between the points K and B must be accompanied by a grid voltage of magnitude $-\frac{M'}{L_1} v_a \sin \omega t$. From the oscillation characteristic it is possible to draw out the anode current variations consistent with these potential changes. These in general will not be sinusoidal and may be expressed as a Fourier series

$$i_a = i_{a0} + i_{a1} \sin \omega t + i_{a2} \sin 2\omega t + \ldots . \\ + i'_{a1} \cos \omega t + i'_{a2} \cos 2\omega t + \ldots .$$

The first term of this series represents the rise or fall of the mean anode current as read by a direct reading instrument when the oscillation begins. Now to a sinusoidal change of angular frequency ω the oscillatory circuit acts as a non-reactive resistance of value $\frac{L_1^2\omega^2}{R}$ and we may thus write

$$i_{a1} = \frac{v_a}{\frac{L_1^2\omega^2}{R}}$$

The conditions of stability are thus such that the anode voltage change $v_a \sin \omega t$ with its attendant grid voltage change $-\frac{M'}{L_1} v_a \sin \omega t$ should produce anode current variations the fundamental component of which has the maximum value $\frac{v_a R}{L_1^2\omega^2}$. Such a value of v_a can only be obtained by means of a tedious harmonic analysis of the oscillation characteristic but such appears to be the only method available for unsymmetrical cases.

The "Feedback" or "Regenerative" Valve Circuit.*

A suit for infringement of Claims 1, 2, 3, 5, 8, 9, 12, 14, 15, 16, 17, and 18 of U.S. Letters Patent No. 1113149 of October 6th, 1914 (on application filed October 29th, 1913), issued to Edwin H. Armstrong for "Wireless Receiving System," in which Edwin H. Armstrong and the Westinghouse Electric and Manufacturing Co. were plaintiffs against the de Forest Radio Telephone and Telegraph Co., has recently terminated by a judgment in favour of the plaintiffs. The suit was tried by District Judge J. M. Mayer, extracts from whose judgment are reprinted below.

MAYER, *District Judge*:—

This is a suit of major importance. It concerns an invention of high merit and the cause

* Extracts from report of the judgment received from Messrs. Pennie, Davis, Marvin and Edmonds, Councillors at Law, New York.

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has been presented ably and comprehensively. While the record is voluminous, it differs from some long records in that, by reason of the issues of fact involved, its length is fully justified. The defences are many but the principal attacks are directed against the priority of Armstrong. It is claimed for Armstrong that his date of invention is at least as early as January 31st, 1913, and thus antedates Schloemilch and Von Bronk, Meissner, and de Forest. Before discussing the questions involved in the priority contest, it is desirable to ascertain what the patent is and what is its accomplishment.

At the outset, it should be stated that the Armstrong feed-back circuit, as it has come to be known familiarly, must be recognised as a contribution of marked value to the practical art. Its employment has so greatly increased both the loudness and the definition of the sounds heard in the receiver that long distance radio communication has been remarkably improved and thus greater reliability has been attained.

"The present invention," Armstrong stated in his specification, "relates to improvements in the arrangement and connections of electrical apparatus at the receiving station of a wireless system, and particularly a system of this kind in which a so-called 'audion' is used as the Hertzian wave detector, the object being to amplify the effect of the received waves upon the current in the telephone or other receiving circuit, to increase the loudness and definition of the sounds in the telephone or other receiver, whereby more reliable communication may be established, or a great distance of transmission becomes possible. To this end I have modified and improved upon the arrangement of the receiving circuits in a manner which will appear fully from the following description taken in connection with the accompanying drawings. As a preliminary, it is to be noted that my improved arrangement corresponds with the ordinary arrangement of circuits in connection with an audion detector to the extent that it comprises two interlinked circuits; a tuned receiving circuit in which the audion grid is included, and which will be hereinafter referred to as the 'tuned grid circuit,' and a circuit including a battery or other source of direct current and the 'wing' of the audion, and which will be hereinafter referred to as the 'wing circuit.' As is usual, the two circuits are interlinked by connecting the hot filament of the audion to the point of junction of the tuned grid circuit and the wing circuit. I depart, however, from the customary arrangement of these circuits in a manner which may, for convenience of description, be classified by analysis under three heads; firstly the provision of means or the arrangement of the apparatus, to impart resonance to the wing circuit so that it is capable of sustaining oscillations corresponding to the oscillations in the tuned grid circuit; secondly, the provision of means supplementing the electrostatic coupling of the audion to facilitate the transfer of energy from the wing circuit to the grid circuit, thereby reinforcing the high frequency oscillations in the grid circuit, and thirdly the introduction into the wing circuit of an inductance through which the direct current of the wing circuit flows, and which is so related to the grid circuit that the maintaining electromotive-force across the terminals of the inductance due to reduction of the direct current, is effective in the tuned grid circuit to increase the grid charge and consequently to further reduce the current in the wing circuit and in the telephones."

The "firstly" and "thirdly" *supra* were in the original specification; the "secondly" was inserted during the prosecution of the patent application.

The first statement is illustrated in the drawings of the patent, and an illustrative claim is No. 1, which specifies, *inter alia*, "a resonant wing circuit" and reads as follows:—

> "1. An audion wireless receiving system having a resonant wing circuit interlinked with a resonant grid circuit upon which the received oscillations are impressed, the resonant grid circuit having a capacity so related to the grid as to receive and retain the charge which accumulates thereon."

The second statement which defines broadly the instrumentalities of the first and third statements is represented by each of the figures of the patent drawings and illustrated by claim 9 which reads as follows:—

> "9. An audion wireless receiving system having a wing circuit interlinked with a resonant grid circuit upon which the received oscillations are impressed, and an inductance through which the current in the wing circuit flows, the grid circuit including connections for making effective upon that circuit the potential variations resulting from a change of current in the wing circuit."

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In one form of language or another, what is set forth in the third statement, is embodied in claims 3, 5, 8, 12, 14, and 17. Claim 17 will suffice for illustration :—

> " 17. An audion wireless receiving system having a wing circuit interlinked with a resonant grid circuit upon which received oscillations are impressed and an electrostatic coupling between the circuits supplementing the coupling of the audion to facilitate transfer of energy from the wing circuit to the grid circuit, whereby the effect upon the grid of high frequency pulsations in the wing circuit is increased."

For so difficult a subject matter, the specification and claims as originally filed fared very well in the Patent Office. The first fourteen claims were allowed as filed and they constitute all of the original claims except one originally numbered 13, which was rejected on reference to the Schloemilch and Von Bronk patent. Out of the mass of testimony and argument too extensive to quote or to discuss in complete detail, it is well to settle one proposition at the start. The Armstrong specification and claims show that the invention was for an instrumentality. The feed-back circuit was well defined in the record on a number of occasions. Professor Hazeltine, plaintiff's expert, stated that the fundamental principle of Armstrong's invention was " the provision of an arrangement for transferring oscillating current energy from the plate circuit to the grid circuit whereby oscillations present in the grid circuit are assisted." " Any arrangement by which oscillating current energy is transferred from the output or plate circuit of the audion to the input or grid circuit to sustain the oscillations in the grid circuit is included in the principle of the Armstrong invention."

Defendant asserts that the question is whether the invention resides in the reamplifying audion or in the oscillating audion or in both or in " some more basic idea " and then contends that the patent is limited by its own terms to the reamplifying audion.

All of these arguments and all the analysis of the Armstrong patent language and claims come down to a single proposition. If Armstrong invented a new instrumentality he is entitled to the fruits of all its uses, whether he understood them or not and whether his theory of operation was right or wrong, comprehensive or limited. Given the new instrumentality the question is what it does, not how or why it does something. It is urged that the error of the argument for Armstrong is " primarily in the assumption that the invention is a specific recognisable thing called a ' feed-back,' a definite group of mechanical or electrical elements which like a tool may be used for various purposes." *That* is not the invention. The invention is ". . . a particular use of an otherwise old circuit by an adjustment of the constants so as to *produce reamplification.*"

The discussion of the limitations upon the patent by its own terms includes quotations from the patent at those places where Armstrong pointed out that if the ratio of feed-back coupling exceeded a certain amount, the audion would become a high-frequency generator setting up disturbing oscillations in the grid and wing circuits and informed the art how maximum amplification of damped wave signals could be obtained below oscillation. But, the fact is that defendant's oscillating audion does regeneratively feed back energy from the plate circuit to the grid circuit to amplify cumulatively the received signals. This seems satisfactorily shown by Hazeltine, by Dr. Austin's paper and by Armstrong's paper, and his testimony in the Interference Record. The patent does not indicate any use of the audion in the oscillating condition, but when the audion is oscillating, due to feed back, it is coincidently regenerating.

Leaving now the construction of the patent as it is written and the action and results which occur from following the teaching of the patent, it is next desirable to ascertain Armstrong's date of invention.

This case is another contribution to the romance which has so often characterised the history of forward inventions. Armstrong was graduated at about twenty-two years of age from Columbia University in June, 1913, as an electrical engineer. As a boy of fifteen he became interested in radio and erected a radio station at his home. He obtained his first vacuum tube detector, a so-called Fleming valve, in 1908 from Mr. Charles R. Underhill. Later, about 1910 or 1911 he obtained a so-called de Forest audion or three-element vacuum tube detector. In the spring of 1912, he began a close study of the fundamental action of the audion and read all the literature on the subject.

Some time during this period he connected a condenser across the telephone of a simple audion receiving system and noticed that on some bulbs an increase in signal strength would

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result. It is important, at this point, to realise that Armstrong is a remarkably clear thinker. His modest demeanour belies his extraordinary ability. His achievement was not the result of an accident, but the consummation of a thoughtful and imaginative mind. Step by step he proceeded with study and experiment from the summer of 1912 until the fall of that year. The apparatus which he used—the long wave apparatus and short wave apparatus—are in evidence. He was obtaining what seemed to him remarkable results and he showed his apparatus to his father and let him listen to his signals and asked his father to advance money for a patent application. Mr. Armstrong, Sr., was evidently not impressed and refused his son financial help. On December 7th, 1912, Armstrong told his college mate Burgi that he had succeeded in improving the sensitiveness of the audion by means of a new connection and Burgi noted this in his diary on that date as follows : "Armstrong told me he had a connection for intensifying sound." About the end of 1912, he explained to Mr. Thomas Ewing that he wished to make tests with a new receiver he had invented and obtained Mr. Ewing's permission to string the antenna (Armstrong having erected a mast at his home) into Mr. Ewing's adjoining property.

About the same time Armstrong showed the receiver to his uncle, Mr. Smith, and tried to get him to advance money for the patent application. This Mr. Smith did not do, but advised Armstrong to make a drawing of the connections and have it witnessed by a notary. During the fall of 1912 and the winter of 1912—1913, Armstrong showed his receiving results to a number of radio amateurs without disclosing the circuits. The description by the amateurs of the result corresponds with what the court heard at the trial during the demonstrations at Columbia University. The amateurs testified that they knew now (*i.e.*, when they testified) that this result must have been produced by the Armstrong feed-back. The testimony of the amateurs is impressive as to its truth and as to accuracy of recollection.

On January 31st, 1913, Armstrong went with his college mate Burgi to Goodwin's Real Estate Office at 123rd Street and Lenox Avenue with a drawing on tracing cloth of his circuit connections and had the drawing witnessed by the notary. It was shown to Armstrong's uncle, Mr. Smith, at about the time it was made, although Mr. Smith did not have such knowledge of wireless apparatus or systems as would enable him to understand the circuits. Burgi testified that he might have understood the circuits at the time but would not be able to reproduce them from memory, but he identified the sketch as the one shown to him and witnessed by the notary in his presence. This drawing is reproduced in the patent as Fig. 2 and it includes both the adjustable tuning inductance in the plate circuit and the telephones located in the common path.

I have no doubt, whatever, either as to the existence of the apparatus on January 31st, 1913, which contained Armstrong's feed-back circuit arrangement and operated practically and successfully or of the accuracy of the date on the drawing of January 31st, 1913. That drawing was a record of an invention then completed and reduced to practice. Armstrong had one objective upon which he concentrated all there was in him of ability, of perseverance, and of courage against what were great odds to a young man.

That no one of the witnesses saw or understood the circuits is, in the circumstances of this case, immaterial and unimportant. I see no legal obstacle to fixing January 31st, 1913, as at least the date of the invention, and I am so completely satisfied with the evidence that I am not embarrassed by any question of fact.

On questions of invention date, much is said about corroboration, but I do not understand that corroboration in the sense of full knowledge by a witness of the inventive conception and an understanding of the apparatus in addition to the inventor is necessary. The question always is as to what will satisfy the trier of the facts ; and, in the case at bar, there is not only Armstrong's testimony to which I accord absolute credibility, but in addition, the apparatus and the sketch—physical things—the testimony of the amateurs and all the surrounding circumstances leave no doubt that Armstrong's date is at least as early as January 31st, 1913.

Considering the difficulties with which the young student was confronted, he moved diligently and finally succeeded in filing his application for the patent on October 29th, 1913.

The merit of the invention was soon recognised and the very apparatus with which Armstrong made the invention was subsequently utilised commercially at Sayville, Long Island, shortly after the outbreak of the war in 1914, to overcome difficulties in the reception of signals from Nauen, Germany, and this apparatus continued in use at Sayville for some time.

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As indicative of the appreciation of the commercial value of the invention, licences were taken at an early date by the Atlantic Communication Company, the Goldschmidt Company and the Marconi Company.

The Meissner United States application was filed on March 16th, 1914. The oath recites four German applications, the earliest of which was dated April 9th, 1913. This application (now German Patent No. 291604, dated June 23rd, 1919) discloses the regenerative or feed-back circuit adjusted to produce oscillations but it does not state that it is for radio reception and the antenna and ground connections are omitted.

It is unnecessary, however. to discuss this patent in detail because by according to Armstrong the date of January 31st, 1913, he preceded Meissner by about 2½ months.

Schloemilch and Von Bronk, U.S. Patent No. 1087892, issued February 17th, 1914, was filed on March 14th, 1913, subsequent to Armstrong's date, but, in any event, it would not have embarrassed Armstrong ; for it did not occur to Schloemilch and Von Bronk to re-amplify the high frequency variations by feeding them back to the grid circuit. In other words, this patent failed to point out, and its authors evidently did not appreciate, the essential point of Armstrong's invention.

The Reisz patent No. 1234489, filed April 9th, 1913, and issued July 24th, 1917, does not call for discussion.

We thus come to the de Forest defence. It is no reflection on de Forest to observe that in a number of instances in this record his memory has proven faulty. This is not strange. During the years 1912, 1913, and 1914, de Forest was confronted with many difficulties and many obstacles. He had much to contend with and, besides, he was experimenting in numerous directions and, in such circumstances, independent memory is not always reliable.

The work with the audion from 1912 to 1914 had to do primarily with two uses of the audion (1) as a telephone relay and (2) as an amplifier of telephone and detected radio signals and the use of the amplifier to record radio signals on a telegraphone wire. The " howling " of an audion oscillating at audio frequencies would defeat both of these purposes for the obvious reason that the noise of the " howling " audion would destroy telephone conversation and radio signals alike. On the other hand, the feed-back circuit would have been of great service in the amplification of radio signals and in recording them on a telegraphone wire.

The documentary evidence of the work of de Forest and his associates begins with the entry in the de Forest experimental notebook (under date of June 21st, 1912), where he enters the observation of a beat or high-frequency note with the straight audion hook-up. His notes show this to have been transient and incapable of reproduction and he recognised that it was not the true heterodyne effect.

The entry of June 21st, 1912, so far as it is pertinent to the present inquiry, shows that de Forest did not then know how to produce a beat note with an audion receiver.

The next entry is in the Van Etten notebook under date of August 6th, 1912. Van Etten was working on the audion as a telephone relay and amplifier. He had looked up the two-way telephone relay in Kempster B. Miller's well-known work on the subject of telephone engineering and had learned that a mechanical telephone relay when used in a two-way circuit would sing and howl unless precautions were taken to prevent it.

On July 23rd, he entered in this notebook a two-way telephone circuit using two audions under the heading " Think the following arrangement (doped out yesterday) would possibly make a good telephone repeater." It happened as de Forest testifies that they did not have two audions available and on July 24th Van Etten attempted to set up this two-way circuit of his with a single audion having two grids and two plates. The arrangement did not work because as Van Etten said in an entry dated August 5th " Above n. g. because audion does not get in the game—simply two repeater coils in series—see inked ckt."

The following day, August 6th, he connected the input circuit of a double audion to the output circuit and in this accidental way found that the audion would howl or sing. He pointed out in his notes that the arrangement gave a beautiful clear tone which lowered and raised in pitch as the B-battery was varied, and could be wiped out by a magnet " and then the watch ticks came through as before." He says " This phenomenon is apparently similar to the ' howl ' produced in an ordinary C B telephone when the receiver is placed against the transmitter but nevertheless as shown by variation of number of cells in battery B and by magnetic wiper is also intimately associated with the audion."

On the same day he set up a balanced two-way telephone circuit corresponding to the

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two-way balanced telephone circuit shown in Miller which is used to prevent the howling of mechanical telephone relays, and made the entry "Tried following circuit, but it was n. g., could not make it boost at all, could only make it howl."

From this point on his notes show a continuing attempt to produce a telephone relay circuit in which the audion would not howl and in this effort he succeeded on or about August 29th, 1912.

The August 6th, 1912, entry of Van Etten was not copied in the laboratory notebook nor was anything done which showed that any one appreciated the phenomenon. De Forest's testimony on the point is not sufficiently clear and definite to be satisfactory.

The entry of February 7th, 1914, shows that where de Forest duplicated the arrangement he referred to it as "This new and simplified circuit" and regarded it as useful only for the "trigger effect." In de Forest's article in the *Electrical World* on February 20th, 1915, no mention is made by de Forest of the August 6th, 1912, entry of Van Etten.

On August 29th, after entering in his own notebook the two-way circuit which did not howl, Van Etten made an entry showing the use of two audion amplifiers in cascade. He explained this arrangement to de Forest, it was considered of great importance, and was copied into de Forest's notebook by Van Etten under that date.

This is the invention de Forest afterward sold to the A. T. & T. and about which he said "When I made this interesting discovery I lost interest in the oscillating feature."

In the Van Etten notebook it is described merely as an amplifier, but in the de Forest notebook it is noted that by reversing certain connections the arrangement makes all sorts of musical notes in the telephones and that the notes could be changed by putting very small capacities, such as the capacity of one's body or from thumb to finger, between ground and grid, wing or filament.

It is testified by de Forest that these effects were due to a feed-back brought about by the fact that the coils numbered 1 and 5 on the sketch were placed close together on the table, although there was no indication of that in the sketch or notes. Van Etten fails to corroborate him as to the existence of any feed-back in this circuit.

Although there was in fact an accidental capacity feed-back between the output circuit of the second audion and the input circuit of the first audion in this cascade system, that coupling was not apparent in the diagram, was not mentioned in the notes, and was not understood by de Forest.

The arrangement did not indicate to de Forest or Van Etten how to control the oscillations, or that they were due to any circuit arrangements, and not due to some peculiar and obscure characteristic of the audion.

Without indulging in further detail, it is enough to say that the proof falls far short of any conviction that in 1912 either de Forest or Van Etten had any realisation of what is now the invention of the patent in suit.

The first application by de Forest of the oscillating audion to any useful purpose was in a laboratory experiment on April 17th, 1913. The entry on that date beginning "This day I got the long looked for beat note" indicates that, theretofore, de Forest had not been able to get this heterodyne phenomenon. There was no sketch of the circuit arrangement nor was the circuit disclosed to any one, scientist or layman. It is argued that, for several reasons, the circuit described in the note was not a feed-back circuit, but, whichever way the entry may be construed, it is at least open to debate and in view of the lack of corroborating circumstances, a debatable entry not clearly illustrated and not disclosed to any one at the time, leaves the matter in doubt. The de Forest notebook entries of 1914 need not be analysed in view of Armstrong's date.

It was not until September, 1915, that de Forest filed any application showing what he claimed to be a feed-back circuit, and in the meantime he had filed thirty patent applications.

Armstrong's counsel do not contend that de Forest's lack of knowledge that the ultraudion circuit was a feed-back circuit would deprive him of whatever benefit might accrue to him from the invention of that circuit in the spring of 1914; but it is their contention that the invention of the ultraudion circuit in February, 1914, the failure to recognise it as a feed-back circuit, and the filing of the ultraudion applications without including any circuit of the 1912 notes, completely negative the idea that he had invented the feed-back circuit in 1912. With this view I agree.

It is not practicable to discuss the testimony in all its elaborate detail. All has been con-

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sidered, although some has not been mentioned, such as that of Logwood, which needs no serious comment. On the one side is an enthusiastic, never-say-die young student—feed-back Armstrong—with but one thought possessing him. He not only discloses to many persons his belief that he has invented something worth while but he produces his apparatus and he produces a sketch which is extraordinary for its clear and unmistakable description to one skilled in the art and the date of that sketch is incontrovertibly fixed.

On the other side is a then experienced and able worker in the art experimenting along certain lines who is unable to rely solely on notebook entries which are not clear but require construing and who supplements these entries by recollection which is fallible and not certain.

If de Forest in 1912 or 1913 invented the feed-back circuit the obvious financial reward in store for him would have induced him, notwithstanding all his difficulties, to do one of two things (1) that which Armstrong did, that is, in some way make a clear memorandum and have somebody know about it or (2) file an application for a patent in the same way that during the period concerned he filed many other applications.

Holding, then, that Armstrong is the first inventor and that his claims in suit should be construed as he contends the sole remaining question is that of infringement. It will suffice to say that on this branch of the case I accept Hazeltine's testimony, from which it appears that all the claims are infringed.

Plaintiffs may have a decree in accordance herewith, with costs.

JULIUS M. MAYER,
District Judge.

May 17th, 1921.

Receiving Valve Patent Action.

In an action for infringement of patents between Marconi's Wireless Telegraph Co., Ltd., plaintiffs, and A. W. Gamage, Ltd., defendants, the following judgment was delivered by Mr. Justice Eve on July 12th, 1921 : —

" Upon motion made unto this Court this day by counsel on behalf of the above-named plaintiffs and upon reading the statement of claim and particulars of breaches filed in this action and the plaintiffs and defendants by their counsel consenting to this order

" This Court doth order that the defendants their servants agents and workmen be restrained during the continuance of the plaintiffs' Letters Patent No. 13636 of the year 1913 and No. 28413 of the year 1913 and any extension thereof or of either of them from infringing the said Letters Patent and each of them.

" And it is ordered that the defendants do pay to the plaintiffs within fourteen days from the date of this order the sum of £150 as the agreed damages sustained by the plaintiffs by reason of the infringement of the said Letters Patent by the defendants.

" And it is ordered that the defendants do forthwith upon oath destroy by dismantling and breaking up into their constituent parts all articles and apparatus being receiving systems or apparatus for receiving electric oscillations (including " Polaris " receiving apparatus) made or used by the defendants in infringement of the said Letters Patent as aforesaid which are in the possession custody or power of the defendants or their servants or agents or workmen.

" And it is ordered that the defendants do pay to the plaintiffs their costs of this action such costs to be taxed by the taxing master."

The patents referred to above were issued to C. S. Franklin and H. J. Round respectively, and cover the use of magnetic retroaction coupling between the anode and grid circuits of a receiving valve, and the use of the detecting valve for also producing local oscillations to set up beats with the incoming signals (autodyne). [3689]

Notes.

Personal.

Mr. M. A. Noss has been appointed chief engineer of the Telepost Co. of New York, and is engaged in wire and radio communication research in conjunction with **Mr. P. B. Delany.** [3135]

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K. A Christiansen has left the Federal Telegraph Co., Palo Alto, California and joined the Pacific Telegraph and Telephone Co. of San Francisco, Cal. [3141]

Mr. Churchill has accepted the chairmanship of the Imperial Communications Committee. The Inter-departmental Imperial Communications Committee was established in 1919 under the chairmanship of the Colonial Secretary (Lord Milner). It has under control matters connected with cable, wireless, and air communication. [3364]

Professor Edouard Branly has been awarded this year's Nobel Physics Prize for his researches in connection with radio work. [3365]

Commercial and General.

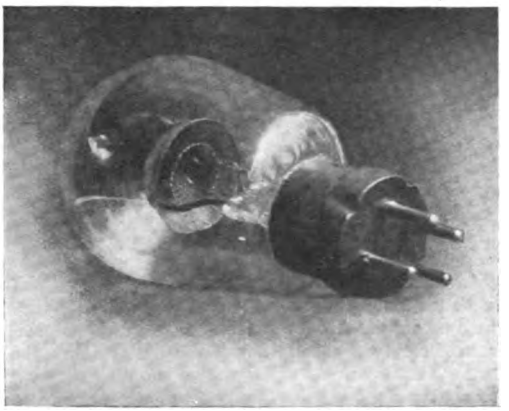
The Compagnie Générale de Télégraphie sans Fil has concluded a contract for a period of thirty years with the Government of Ecuador for the working of the telephones, telegraphs and wireless service in that State. The Government of Ecuador will pay the company an annual subsidy of about 1,200,000 francs. The State will have a share in the net profits. [3036]

The new wireless station at Port Elizabeth (S. Africa), which was opened on May 3rd, has a guaranteed daylight range of 300 miles, but tests have shown the possibility of communicating over 1,000 miles under favourable conditions at night. The power of the station is 1½ kW, and the aerial is of the umbrella type supported by two 80-ft. masts. [3030]

The number of radio stations operated and controlled in the Australian Commonwealth was recently stated by the Minister of Defence to be twenty, exclusive of naval stations at Garden Island, Jervis Bay (N.S.W.) and Williamstown. In addition to the Commonwealth stations there are eight under the jurisdiction of the Administrator of the New Guinea territory. [3034]

The Japanese Government has erected two new wireless stations at Okinawa (Liu-kiu Islands) and Kogoshima for ship traffic. Military and naval stations are to be built at Hokkaido and Otaru at a cost of 6 million yen. [3032]

A demonstration was recently given by Messrs. R. M. Radio, Ltd., at their new premises, 5, Regent Square, W.C. 1, of their ship installations — recently described in these columns—and of a new pattern of triode receiving valve which is the invention of Captain H. de A. Donisthorpe. This valve has a hemispherical anode and grid mounted over a loop filament, and is of the "soft" variety. When in use a coil is placed round the bulb, and a direct current from a few cells is passed through its windings. The resulting magnetic field serves to concentrate the streams of ions and electrons into favourable directions under the anode, and improves the qualities of the tube as a detector, a most marked increase in the strength of signals being observed when the coil is in place. The valve is remarkably free from locally produced noises, due to vibration, etc., and this increases its value when receiving weak signals. [3367]



The R.M.R. Triode.

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Review of Radio Literature.

1. Abstracts of Articles and Patents.

(P.) High-frequency Circuits and Measurements.

(2) THEORY OF ELECTRIC CIRCUITS; COUPLING, ETC.

2095. **F. J. W. Whipple.** Equal Parallel Cylindrical Conductors in Electrical Problems. (*Proceedings of the Royal Society*, 96A, pp. 465—475, February 3rd, 1920. *Science Abstracts*, 23A, p. 399, Abstract No. 1004, July 31st, 1920—Abstract. *Journal de Physique et le Radium*, Abstract Supplement p. 35, August, 1920—Abstract.)

A more general treatment of a problem previously discussed by A. Russell enabling the current density and the magnetic flux to be calculated for high-frequency currents flowing in long parallel conductors.

2096. **E. Bellini.** Three-magnetically Coupled Circuits. (*Electrician*, 85, p. 78, July 16th, 1920. *Science Abstracts*, 23A, pp. 586—587, Abstract No. 1476, November 30th, 1920—Abstract. *L'Elettrotecnica*, 7, p. 615, December 5th, 1920—Abstract. *Revue Générale de l'Électricité*, 8, p. 109D, October 9th, 1920—Abstract.)

A mathematical discussion of three inductively coupled circuits tuned to the same frequency. It is concluded that a frequency of the oscillations in the two extreme circuits always remains that of the common frequency to which all the circuits are tuned, however close the couplings may be, and also that two coupling frequencies exist in all three circuits. Some experimental results are given confirming these conclusions. In the case when the intermediate circuit has no condenser it is shown that the extreme circuits possess two frequencies, while in the intermediate circuit only one of them is present.

2097. **J. R. Carson.** Theory and Calculation of Variable Electrical Systems. (*Physical Review*, 17, pp. 116—134, February, 1921.)

The paper deals with the extension of the theoretical methods of solution of invariable electrical systems to include variable systems in which one or more of the circuit elements are definite functions of time, or in which the relation between current and applied E.M.F. is non-linear. This is done by the application of integral equations.

The application of the method is given to a number of radio problems, including the circuit equations of the Goldschmidt H.F. alternator, the three-electrode valve, microphone transmitter, etc.

2098. **F. C. Blake.** On Electrostatic Transformers and Coupling Coefficients. (*Journal of the American Institute of Electrical Engineers*, 40, pp. 23—29, January, 1921. *Science Abstracts*, 24B, p. 156, Abstract No. 307, March 31st, 1921—Abstract. *Physical Review*, 15, p. 340, April, 1920—Abstract.)

Starting from the experimentally determined fact that the capacity of an air condenser is independent of the frequency of electrical oscillation, it is shown by means of Lord Rayleigh's equations for the mutual reactance between two circuits each having inductance, resistance and capacity, that for high-frequency conditions when the resistance is negligible compared to the reactance, the capacity reaction between the two circuits can be expressed best in terms of elastances. Definitions are given for self and mutual elastances as well as for self and mutual capacitances and the definitions are tested by our knowledge of spherical condensers. The coefficient of elastic coupling is shown to be the ratio between the mutual elastance and the square root of the product of the two self elastances, the analogy with the coefficient of inductive coupling being exact. The coefficient of capacitive coupling between two circuits each having capacity with a capacity in the branch common to both is shown to be a limiting case of the coefficient of elastic coupling and thereby a condenser of the ordinary or close form is shown to be an electrostatic transformer with a coupling coefficient of unity. The true relationship between Maxwell's coefficient of capacity and the elastances or capacitances is pointed out in the case of the spherical condenser. The ideas developed are applied to the thermionic tube and thereby the behaviour of the ultraudion and the experiments of

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van der Pol are readily explained. Attention is called to the alternative view of the behaviour of condensers toward alternating currents, viz., instead of being paths of low impedance, they are paths of ready yielding or low stiffness or elastance, as suggested by Heaviside and by Karapetoff.

2099. **A. Press.** Q_m-Operators and Hysteresis Harmonics. (*Electrician*, 86, pp. 72—73, January 14th, 1921. *Science Abstracts*, 23B, Abstract No. 154, p. 79, February 28th, 1921—Abstract. *Revue Générale de l'Électricité*, 9, pp. 805 806, June 4th, 1921.)

An extension of earlier work on Q_m-operators,* and in particular an investigation of the justification of the assumption made in the earlier work that adding current harmonics on the primary side of a transformer was equivalent to superposing linearly the corresponding voltage harmonics on the secondary side obtained independently by means of the $B-H$ curve. It is concluded that where the width of the hysteresis loop is not too great, the assumption is justified.

2100. **A. F. Zahm.** Harmonic Oscillations. (*Journal of the Franklin Institute*, 191, pp. 381—404, March, 1921.)

A mathematical study of harmonic motion.

2101. **A. Hund.** Complex Angular Velocities and their Application to Electrical Problems. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 431—457, December, 1920; 17, pp. 40—50, January, 1921: pp. 98—118, February, 1921.)

Translation of a paper in the *Proceedings of the Institute of Radio Engineers*.†

2102. **A. W. Porter** and **R. E. Gibbs.** On Systems with Propagated Coupling. (*Philosophical Magazine*, 41, pp. 432—440, March, 1921.)

In the majority of electrically coupled circuits the two circuits are so close together that the time of propagation of the mutual action between them can be neglected. For great distances of separation, or for very high frequencies, this would no longer be true, and the mathematical theory of this effect is given in the paper for various cases.

2103. **L. E. Whitmore.** Capacitive Coupling in Radio Circuits. (*Physical Review*, 15, pp. 559—562, June, 1920.)

Equations are derived for an electrostatic coupling of two oscillation circuits by means of two condensers and formulæ are derived for the frequencies of the coupling oscillations. The conclusions are supported by cathode ray oscillograms.

2104. **C. S. Perkins.** A Study of Electrical Resonance in Radio Transmitters. (*Wireless Age*, 8, pp. 23—24, February, 1921.)

2105. **W. Rogowski.** The Damping in Two Inductively Coupled Oscillatory Circuits with Tight Coupling. (*Archiv für Elektrotechnik*, 9, pp. 427—438, March, 1921.)

A theoretical investigation intended as an introduction to a later paper on the phenomena occurring in a triode oscillator with coupled oscillatory circuits. The coupled frequencies are first determined for various ratios of natural frequencies, neglecting resistance. An approximate solution is then obtained for the case when the resistances are small but not negligible. The method is based on the supposition that the resistance alters the coupled frequency from Ω to $\Omega' = \Omega(1+\xi)$ where ξ is so small that on expanding powers of $1+\xi$, all powers of ξ above the first may be neglected. It is then shown that the voltage $V_1 = Ae^{i\Omega' t} = Ae^{i\Omega t}e^{i\xi\Omega t} = Ae^{i\Omega t}e^{-at}$, that is to say that the frequency is not appreciably changed but the oscillation has a damping index

$$\alpha_1 = \frac{R_1}{2L_1}U_1 + \frac{R_2}{2L_2}U_2$$

for the high-frequency oscillation and

$$\alpha_2 = \frac{R_1}{2L_1}u_1 + \frac{R_2}{2L_2}u_2$$

for the low-frequency oscillation.

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* See RADIO REVIEW, 1, pp. 575—576, August, 1920.

† See RADIO REVIEW Abstract No. 1186, December, 1920.

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Formula are developed for the weighting factors U and u, and the results discussed and illustrated by means of curves.

2106. **A. Mestraup.** On an Electrical Analogy for Undamped Oscillations. (*Revue Générale de l'Électricité*, 9, pp. 363—368, March 12th, 1921.)
The oscillations set up by a series dynamo are discussed mathematically.

2107. **P. Joye** and **M. Besoson.** Distributed Capacity in Transformers and Induction Coils; The Discrepancy between Theory and Experiment. (*Bulletin of the Schweizerische Elektrotechniker Verein*, 12, pp. 37—41, February, 1921. *Science Abstracts*, 24B, p. 196, Abstract No. 393, April 30th, 1921—Abstract.)

2108. **R. B. Abbott.** Damped Electric Oscillations. (*Physical Review*, 17, pp. 482—492, April, 1921; pp. 510—511, April, 1921—Abstract.)
A summary of previous work is given with references to important papers. This is followed by a mathematical treatment of damped oscillations with solutions of the differential equations for four types of oscillations: (1) simple harmonic; (2) logarithmically damped; (3) linearly damped; and (4) combined logarithmically and linearly damped oscillations. The mathematical treatment is simplified by an analogy between the dynamical and electrical differential equations of motion.

(3) AND (4) INDUCTANCES AND CONDENSERS (THEORY, DESIGN, ETC.).

2109. **C. O. Gibbon.** Design of Air Core Inductance Coils of Minimum Weight for a given Inductance and Resistance. (*Journal of the American Institute of Electrical Engineers*, 39, pp. 660—665, July, 1920. *Electrical World*, 76, p. 647, September 25th, 1920—Abstract. *Technical Review*, 7, p. 426, December 28th, 1920—Abstract. *Science Abstracts*, 23B, p. 416, Abstract No. 796, September 30th, 1920—Abstract. *Revue Générale de l'Électricité*, 8, p. 129D, October 23rd, 1920—Abstract.)

2110. Physical Society's Exhibition. (*Electrical Review*, 88, pp. 121—122, January 28th, 1921. *Electrician*, 86, pp. 131—133, January 28th, 1921.)
See RADIO REVIEW, 2, pp. 94—97, February; pp. 152—153, March; pp. 201—203, April, 1921.

2111. **F. W. Grover.** The Inductance of Coils wound on Polygonal Forms. (*Physical Review*, 15, p. 532, June, 1920.)
An abstract of an American Physical Society paper dealing with a comparison of the inductances of coils wound on circular and polygonal forms. Tables of equivalent radii have been calculated.

2112. **F. Duroquier.** Multilayer Inductance Windings. (*La Nature*, 49(1), Supplement pp. 107—108, April 2nd, 1921.)
Illustrated constructional details.

2113. **B. Steinmetz.** Multilayer Inductances for Long Waves. (*Wireless Age*, 8, pp. 29—30, January, 1921.)

2114. **W. Geiss.** Natural Frequency and Harmonics of Single Layer Coils. (*Annalen der Physik*, 64, pp. 377—400, February 24th, 1921. *Science Abstracts*, 24A, p. 295, Abstract No. 711, April 30th, 1921—Abstract.)
A description of experiments made to check Lenz's formulæ for the natural frequency of coils, and also the relation of the harmonic frequencies to the fundamental. Experiments were made with both short and long coils, and the results were found to agree with theory.

2115. **A. Esau.** Self-inductance of Multi-layer Coils. (*Jahrbuch Zeitschrift fur drahtlose Telegraphie*, 15, pp. 2—26, January, 1920. *Science Abstracts*, 24A, p. 299, Abstract No. 720, April 30th, 1921. *Electrical World*, 75, p. 1207, May 22nd, 1920—Abstract.)
See RADIO REVIEW Abstract No. 329, May 1920.

2116. **L. Segal.** Condenser. (*French Patent* 502781, July 8th, 1919. Published May 26th, 1920. *British Patent* 146925, March 5th, 1920. Convention date July 8th, 1919.)
The specification describes a polyphase condenser comprising a number of conducting plates coiled about a common axis with a di-electric material between the layers.

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2117. **Galvanophoren-Werke (System Vogt.) S. Szubert, Commandit-Gesellschaft and Vereinigte Elektricitats-Werke, G.m.b.H.** Condenser. (*French Patent* 506651, November 20th, 1914. Published August 27th, 1920.)

The specification describes a process of manufacturing electrical condensers so that the groups of plates form a solid block with the separating elements. The plates are formed by casting and the separating material is introduced by injection. There are no drawings to the specification.

2118. A New Type of Variable Condenser. (*Q.S.T.*, 4, p. 19, August, 1920.)

Describes a variable condenser in which the distance between the plates is the variable factor.

2119. **A. W. Isenthal.** Electric Condensers. (*British Patent* 153858, October 28th, 1919. Patent accepted November 18th, 1920.)

An adjustable condenser for tuning oscillatory circuits and other uses; the capacity is varied by unwrapping or wrapping one of the plates on the surface of a thin dielectric which is mounted on the surface of a metallic drum. The metal plates may be of triangular form or of any shape to give any desired scale calibration.

2120. **M. Adam.** The Construction of a Variable Condenser. (*Radioélectricité*, 1, pp. 602—603, May, 1921.)

(5) AND (6) MEASUREMENTS OF H.F. INDUCTANCE, CAPACITY, DECREMENT, ETC.

2121. **Research Laboratories of the American Telephone and Telegraph Company and of The Western Electric Company, New York** A High Frequency Bridge. (*Electrical World*, 77, p. 163, January 15th, 1921.)

A short note with regard to the development of a bridge for frequencies up to 10^6 cycles per second. An accuracy of less than $\frac{1}{4}$ per cent. is obtainable.

2122. **F. C. Blake.** On the Effective Capacity and Resistance of a Condenser for High Frequency Currents. (*Physical Review*, 16, pp. 540—557, December, 1920; and 15, p. 148, February, 1920—Abstract. *Electrical World*, 77, p. 102, January 15th, 1921—Abstract. *Science Abstracts*, 24A, p. 222, Abstract No. 524, March 31st, 1921—Abstract.)

Experiments are described for measuring the capacity of condensers arranged to form the end condensers of a Lecher wire system. It is found that the capacity of such condensers is independent of the frequency of the oscillations. Rayleigh's equation for the effective stiffness of the circuit due to the mutual reactions between two circuits each containing inductance, capacity and resistance is verified. Use is made of the above equation for effective resistance to determine the mutual resistance of two reacting circuits.

2123. **F. C. Blake** and **C. Sheard.** On the Dielectric Constant of Kerosene and Water for High-frequency Currents. (*Physical Review*, 15, pp. 148—149, February, 1920.)

2124. **E. Giebe** and **E. Alberti.** Capacity Effects in High-frequency Measurements. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 242—251, October, 1920. *Science Abstracts*, 24B, pp. 212—213, Abstract No. 429, April 30th, 1921—Abstract. *Radioélectricité*, 1, p. 99D, March, 1921—Abstract.)

2125. **J. J. Dowling.** Sensitive Valve Method for the Measurement of Capacity. (*Proceedings of the Dublin Royal Society*, 16, pp. 175–184, December, 1920. *Science Abstracts*, 24A, p. 299, Abstract No. 719, April 30th, 1921—Abstract.)

In its simple form the apparatus used in this method was arranged as follows:—One terminal A of an A.C. source was connected directly to the negative end of the filament of a valve, and also through a milliammeter or, preferably, a sensitive galvanometer, to the negative terminal of the anode battery. A was also connected through a resistance of 0·5 megohm to the grid and thence through the condenser C under test to the other terminal of the A.C. source. The filament battery was shunted by a potentiometer and a tapping from this was joined through a 10,000 ohm resistance to the negative terminal of the anode battery, the positive terminal of which was joined directly to the anode. If the greater part of the anode current is balanced by the current from the filament battery due to the P.D. across that part of the potentiometer in use, accurate comparison can be made between two condensers of

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nearly equal capacity introduced at C, or a study can be made of slight variations in a single condenser. With the arrangement described above the relation between galvanometer deflection and capacity is almost linear. Unsteadiness of the galvanometer deflections was eliminated by suitable metallic screening and insulation of the various parts of the apparatus.

2126. **E. Merritt.** Polarisation Capacity and Polarisation Resistance as Dependent upon Frequency. (*Physical Review*, 17, pp. 524—525, April, 1921—Abstract.)

Refers to the experiments by G. O. Squier in which high-frequency signals are sent along bare wires immersed in water.* Experiments are described on the electrolytic capacity of platinum wires immersed in acid over a wide range of frequencies. It was found that for frequencies up to one million the capacity is approximately inversely proportional to the square root of the frequency and that for the range of frequencies between half million and four million the variation is more nearly proportional to the reciprocal of the frequency.

2127. A Decremeter for the Amateur. (*Science and Invention*, 9, p. 50 and p. 84, May, 1921.)

Two small glow lamps are used for the comparison of the currents in resonance and out of resonance—one being connected in the wavemeter circuit and the other in series with a local battery.

(7) AND (8) MEASUREMENT OF H.F. CURRENTS, ETC.; H.F. OSCILLOGRAPHS.

2128. **W. H. Wilson** and **Miss T. D. Epps.** The Construction of Thermo-couples by Electro-deposition. (*Proceedings of the Physical Society of London*, 32, pp. 326—340, August 15th, 1920. *Nature*, 105, p. 842, August 26th, 1920. *Engineer*, 130, p. 143, August 6th, 1920—Abstract. *Electrical World*, 76, p. 584, September 18th, 1920—Abstract. *Technical Review*, 7, p. 257, November 23rd, 1920—Abstract. *Scientific American*, 123, p. 443, October 30th, 1920—Abstract. *Science Abstracts*, 24A, p. 137, Abstract No. 303, February 28th, 1921—Abstract.)

The method described consists in using a continuous wire of one of the elements and coating those parts of it which have to form the other element of the couple by an electrolytic deposit of another metal. The short-circuiting effect of the core is generally not serious. Constantan wire coated with either silver or copper sheaths was found suitable.

The construction of multijunction couples for the measurement of high-frequency currents is also described.

2129. **W. F. Powers** and **J. C. Hubbard.** On the Use of Continuous Waves for the Measurement of Dielectric Constants of Liquids. (*Physical Review*, 15, pp. 535—536, June, 1920.)

2130. **J. Guinchant.** The Standardisation of Antenna Ammeters. (*Radioélectricité*, 1, pp. 441—442, February, 1921.)

The method proposed consists in the coupling of a " frame " or coil to the conductor carrying the current to be measured, and reading the voltage induced in the coil by means of an electrostatic voltmeter. If the dimensions of the coil, or frame, are a cms parallel to the long straight conductor, and b cms perpendicular to it, and it is placed with its axis l cms from the axis of the conductor, it is shown that the voltage induced in the coil is given by

$$E = 2a \frac{I}{10} \omega \log_e(1 + b/l) \times 10^{-8}$$

where I is the current to be measured. A more accurate expression is given to allow for the turns of the coil not all being in one plane, but it is shown that the error in the simpler formula is small.

2131. **W. S. Flight.** Spark-over Voltages through Air. (*Beama Journal*, 7, pp. 367—374, November, 1920; pp. 467—474, December, 1920; and 8, pp. 23—29, January, 1921.)

An examination of the published data connected with spark-over voltages through air, and includes the results of additional tests carried out where necessary to amplify the previously published information. The following factors are considered as influencing the

* RADIO REVIEW Abstract No. 854, September, 1920.

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spark-over voltage. Spark length, shape of conductors, proximity of grounded objects, shape of the insulator, density of air, impurities, duration of application of voltage, etc.

2132. **J. B. Whitehead** and **F. W. Lee.** The Electric Strength of Air under Continuous Potentials as influenced by Temperature. (*Journal of the American Institute of Electrical Engineers*, 40, pp. 373—386, May, 1921.)

The critical corona forming electric intensities at several constant temperatures and at various pressures have been investigated for a number of different sizes of wires. The results are given in the form of tables and curves.

2133. **P. R. Coursey.** High-frequency Currents—Their Detection and Measurement. (*Wireless World*, 8, pp. 667—670, December 25th, 1920. *Radioélectricité*, 1, p. 113D, April, 1921—Abstract.)

2134. **W. Rogowski.** Improvements in Cathode Ray Oscillographs. (*Archiv für Elektrotechnik*, 9, pp. 115—120, July 8th, 1920. *Electrical World*, 76, p. 888, October 30th, 1920. *Science Abstracts*, 24A, p. 60, Abstract No. 140, January 31st, 1921—Abstract.)

2135. **J. B. Johnson.** A Low Voltage Cathode Ray Oscillograph. (*Physical Review*, 17, pp. 420—421, March, 1921.)

A short description is given of a tube containing a small quantity of gas and having a Wehnelt cathode. The tube operates on 500 volts, and has higher sensitivity than the usual patterns.

The spot on the fluorescent screen can be seen in daylight, and can be photographed with an ordinary camera in from one to ten seconds.

2136. **A. Dufour.** The Cathode Ray Oscillograph. (*Journal de Physique et le Radium*, 1, pp. 147—160, November, 1920. *Bulletin de la Société Belgé des Électriciens*, 35, pp. 77—79, March—April, 1921—Abstract.)

(9) PROPERTIES OF IRON AT HIGH FREQUENCIES.

2137. **E. F. W. Alexanderson.** Magnetic Losses at High Frequency. (*Electrical World*, 77, p. 163, January 15th, 1921.)

A short note with regard to research on the magnetic properties of iron at high frequencies, from which it was concluded that Steinmetz's laws with regard to hysteresis, eddy currents and skin effects are as accurate at 10^7 cycles as at 25 cycles per second.

2138. **R. G. Loyarte.** Magnetic Permeability of Iron and Nickel for Hertzian Oscillations. (*Science Abstracts*, 24A, pp. 141—142, Abstracts Nos. 311 and 312, February 28th, 1921, abstracted from the *Publications of the University of La Plata*, 1, pp. 453—498, March, 1917, and 2, pp. 105—135, December, 1917.)

An account of experiments on the high-frequency magnetic properties of iron and nickel. Frequencies up to 500 million were used.

2139. **A. W. Smith.** The Effect of a Superposed Constant Field upon the Alternating Current Permeability and Energy Loss in Iron. (*Physical Review*, 17, pp. 416—418, March, 1921.)

2140. **W. Fondiller** and **W. H. Martin.** Hysteresis Effects with Varying Superposed Magnetising Forces. (*Journal of the American Institute of Electrical Engineers*, 40, pp. 149—158, February, 1921. *Science Abstracts*, 24B, p. 243, Abstract No. 489, May 31st, 1921—Abstract.)

An oscillographic study of hysteresis effects in iron subjected to magnetising currents of two frequencies.

2141. **R. Gans** and **R. G. Loyarte.** The Permeability of Nickel at High Frequencies. (*Annalen der Physik*, 64, pp. 209—249, February 9th, 1921.)

After reviewing other work on the subject, it is shown that the damping of the magneton oscillations should cause the induction to lag behind and be no more proportional to the field strength. To examine this point experimentally similar rectangular circuits were made up of nickel wire and of copper wire, and these were alternately connected to the condenser and excited by a quenched spark gap transmitter. Resonance curves were taken and the permeability calculated from the results. The results indicated a decrease of permeability for very high frequencies ($\lambda = 20$ cm); similar results were obtained for iron.

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2142. **R. Gans.** The Permeability of Nickel for Short Hertzian Waves and the Measurements of Arkadiew. (*Annalen der Physik*, 64, pp. 250—252, February 9th, 1921.)

A critical discussion of Arkadiew's results (see *Annalen der Physik*, 58, p. 105, 1919) and a comparison with those referred to in the preceding abstract.

2143. **F. Margand.** On the Question of the Existence of Two Resonant States in Circuits containing Iron. (*Revue Générale de l'Électricité*, 9, pp. 635—637, May 7th, 1921.)

Referring to the theory of the resonant phenomena in such circuits previously put forward by Boucherot.* The author discusses the conditions determining instability of one or more of these states and the influence of capacity, resistance, etc.

2144. **P. Boucherot.** On the Existence of Two Resonant States in Circuits containing Iron. (*Revue Générale de l'Électricité*, 8, pp. 827—829, December 11th, 1920. See also *Comptes Rendus*, 170, pp. 725—728, March 22nd, 1920.)

(Q.) Short Wave Apparatus.

2145. **G. C. Southworth.** Electron Tube Generators of Alternating Currents of Ultra-radio Frequencies. (*Technical Review*, 7, p. 323, December 7th, 1920. *Science Abstracts*, 24A, p. 53, Abstract No. 123, January 31st, 1921—Abstract.)

RADIO REVIEW, 1, pp. 577—584, September, 1920.

(R.) Radio Direction Finding.

(1) AND (2) THEORY.

2146. **E. Bellini.** The Errors of Direction Finders. (*Electrician*, 86, pp. 220—222, February 18th, 1921. *Science Abstracts*, 24B, pp. 213—214, Abstract No. 431, April 30th, 1921—Abstract. *Electrical World*, 77, p. 839, April 9th, 1921—Abstract. *Annales des Postes, Télégraphes et Téléphones*, 10, pp. 336—346, June, 1921—Abstract.)

Various suggestions have been put forward to account for the observed errors at radio direction finding stations. This article discusses the errors that may arise from the reflection of waves from the Heaviside layer—this is considered as homogeneous and continuous—and by the influence of the horizontal parts of the sending antennæ on the horizontal parts of the receiving loops. If a truly vertical transmitting aerial is reflected in a horizontal Heaviside layer the image in space will also be vertical and therefore no effect will be produced on the apparent directions of the waves as observed at a D.F. station; but if the transmitting aerial has a horizontal part the imaginary radiation from the image of that part in the Heaviside layer will also affect the receiving station with the result that in general an elliptical rotating field will be set up. This causes the minimum in many cases to be broad or almost non-existent, so that the bearing is inaccurate. Errors up to 90° are accountable for in this manner and the effect is closely analogous to that observed when bearings are taken on an aeroplane trailing wire aerial.

It is also shown that if the antenna of the D.F. station has no horizontal parts no errors in the bearings would be observed and it is suggested that the double loop receiver used by Weagant † and the special receiving loops of Franklin should furnish exact bearings. As confirmation of the theory observations are cited on the Hanover station which uses a symmetrical umbrella aerial which apparently causes no errors.

2147. **M. Rothé.** The Influence of Atmospheric Conditions on Radio Direction Finding. (*Comptes Rendus*, 172, pp. 1345-1347, May 30th, 1921. *Revue Scientifique*, 59, p. 313, June 11th, 1921.)

A brief account of some experiments carried out at Strassbourg between July 20th and October 10th, 1920, on signals sent out from the Eiffel Tower, Poldhu and Nauen. The object of the tests was to determine whether any variation in apparent direction of the waves in the daytime could be observed corresponding with meteorological changes, and with the changes of signal intensity. It is concluded that during the day the meteorological conditions do not have any serious effect on D.F. work.

2148. **J. Hollingworth.** Directional Measurements with the R.A.F. System. (See pp. 282—301 in June, 1921, issue.)

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* See RADIO REVIEW Abstract No. 2144.

† RADIO REVIEW Abstract No. 18, October, 1919.

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(3), (4) AND (5) D.F. ON LAND, SHIPS AND AIRCRAFT.

2149. **H. Marchand.** Radio Direction Finding. (*Bulletin de la Société Belge des Électriciens*, 35, pp. 3—14, January—February, 1921.)

An illustrated descriptive article dealing with D.F. apparatus manufactured by the Marconi Company.

2150. **Marconi's Wireless Telegraph Company Limited.** Directive Signalling. (*French Patent* 507360, December 12th, 1919. Published September 14th, 1920. *L'Électricien*, 52, p. 115, March 1st, 1921—Abstract.)

The specification describes a transmitting system comprising a number of independent aerials, a separate valve amplifier for each aerial and a central generator to control the oscillations generated by the separate valves. A central dynamo supplies power to each valve or each valve may have a separate source of power.

For further particulars see the corresponding *British Patent* 140538 in the name of **C. S. Franklin.***

2151. **J. Erskine-Murray** and **J. Robinson.** Direction Finding Apparatus. (*French Patent* 507388, December 13th, 1919. Published September 14th, 1920.)

The specification describes apparatus for determining the direction of arriving electromagnetic waves by obtaining equality of signal strength for two positions of a rotary aerial or goniometer coil.

Further particulars may be obtained from the corresponding *British Patent* 136600. (See RADIO REVIEW Abstract No. 506, July, 1920.)

2152. **J. B. Will.** Radio Compasses. (*Proceedings of the U.S. Naval Engineers*, 46, pp. 851—855, June, 1920.)

Gives a general outline of the U.S. Navy arrangement of radio compasses.

2153. **G. W. Littlehales.** The Prospective Utilisation of Vessel-to-Shore Radio Compass Bearings in Aerial and Transoceanic Navigation. (*Journal of the American Society of Naval Engineers*, 32, pp. 38—44, February, 1920. *Journal of the Washington Academy of Sciences*, 11, p. 59, February 4th, 1921—Abstract.)

The method of finding latitude and longitude in aerial and marine navigation from vessel-to-station radio compass bearings is described, and its mathematical theory is expounded.

2154. **H. J. Round.** Direction Finding Apparatus. (*British Patent* 160475, August 19th, 1919. Patent accepted March 31st, 1921. *Engineer*, 131, p. 499, May 6th, 1921—Abstract.)

Deals with an arrangement for compensating the errors in direction finding on board ship using aerials of the Bellini-Tosi type. The aerial in the fore and aft line of the ship is provided with chokes or other means to reduce its receptive qualities.

2155. **A. Perry.** Aeroplanes and Radiogoniometers. (*Radio News*, 2, p. 683, and p. 752, April, 1921.)

A general summary of the uses of D.F. apparatus on aircraft.

2156. **E. C. Hanson.** Aircraft Landing Stations. (*British Patent* 156768, January 7th, 1921. Convention date, March 5th, 1921. Patent not yet accepted.)

Refers to the use of an induction arrangement for enabling the aircraft to locate the landing stations.

2157. **S. O. E. T. Frost.** Directive Wireless Signalling. (*British Patent* 151253, July 17th, 1920. Convention date, July 19th, 1919. Patent not yet accepted.)

An aerial system adapted to the determination of the direction of the waves in three dimensions in space.

2158. **H. R. C. van de Velde** and **J. M. Furnival.** Direction Finding Apparatus. (*British Patent* 161667, January 12th, 1920. Patent accepted April 12th, 1921. *Engineer*, 131, pp. 583—584, May 27th, 1921—Abstract.)

In D.F. apparatus for aircraft the search coil of the radiogoniometer may be controlled by the rudder of the machine so that by keeping the signals at minimum strength the correct course to the W/T station is maintained.

* See RADIO REVIEW Abstract No. 811, September, 1920.

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(6) RADIOPHARES.

2159. **F. A. Kolster.** Development of the Radio Beacon. (*Wireless Age*, 8, pp. 16—17, March, 1921.)

A short illustrated description of wireless D.F. installations on lighthouses in Chesapeake Bay.

2160. **G. P. Grenfell, J. Erskine-Murray, J. Robinson** and **H. L. Crowther.** Radio Direction Finding Apparatus. (*British Patent* 161448, April 23rd, 1920. Patent accepted April 14th, 1921.)

A special arrangement of radiophare is described in which a rotating frame aerial is excited from a coil which is rotated at a slightly different rate. The direction of minimum rotation therefore rotates at a speed equal to the difference of the speeds of rotation of the frame and coil.

2161. **F. Murphy.** Wireless Direction Finding Systems. (*British Patent* 160975, January 13th, 1920. Patent accepted April 7th, 1921.)

See RADIO REVIEW, 2, p. 155, Note No. **2169**, March, 1921, for Abstract.

2162. **J. Erskine-Murray, J. Robinson** and **H. L. Crowther.** Wireless Direction Finding Apparatus. (*British Patent* 160250, December 15th, 1919. Patent accepted March 15th, 1921.)

In a wireless D.F. system a directional transmitting station is adapted to emit successively along compass bearings between north and south a continuous wave of short wavelength which is constant for all directions of transmission and has its amplitude modulated at a supersonic frequency which varies as a function of the direction of transmission.

2163. **J. Erskine-Murray, J. Robinson** and **H. L. Crowther.** Wireless Direction Finding Apparatus. (*British Patent* 160251, December 15th, 1919. Patent accepted March 15th, 1921.)

In a direction finding system of the type in which the frequency of the transmitted wave is a function of the direction of transmission the receiving station is provided with a tuned circuit to give heterodyne effect of high or inaudible frequency, and with another tuned circuit on which the supersonic beats are impressed so that they are reheterodyned to an acoustic frequency.

2164. **J. Erskine-Murray** and **J. Robinson.** Determining Bearings by Wireless. (*British Patent* 158005, April 11th, 1919. Patent accepted February 3rd, 1921.)

Relating to systems where a wireless "beam" rotating at a known rate is transmitted and the receiving station determines its bearing by observing the time-interval between a special signal emitted when the "beam" points north and the moment when the received signals are of maximum or minimum intensity.

2165. **Gesellschaft für drahtlose Telegraphie.** Wireless Direction Finding Apparatus. (*British Patent* 147442, July 7th, 1920. Convention date, June 11th, 1918. Patent not yet accepted.)

For the directive propagation of waves, using widely separated aerials excited by oscillations having a definite phase relation with each other, currents of relatively low frequency and of small intensity are supplied from a central station and are amplified and raised in frequency at the transmitting stations.

2166. **J. Erskine-Murray.** Wireless Navigational Apparatus. (*British Patent* 152758, July 18th, 1919. Patent accepted October 18th, 1920.)

The transmitting station has two rotating directional aerials radiating waves of slightly different frequency; and the receiver uses a heterodyne having a frequency differing slightly from both transmitted waves. When the energy received from one of the rotating aerials is zero, the heterodyne note becomes pure.

(8) GENERAL D.F. APPARATUS.

2167. **E. Bellini.** Wireless Direction Finding Apparatus. (*French Patent* 504014, January 7th, 1918. Published June 23rd, 1920. *Radioélectricité*, 1, p. 93D, February, 1921—Abstract.)

The invention comprises a receiving radiogoniometer in which the conditions of resonance are a function of the angle between the direction of the transmitting station and of the movable member of the instrument, in such a manner that when this angle is 0°, the intensity

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of reception is a maximum. The instrument consists of a magnetic receiver coupled to the aerials by a radiogoniometer loosely coupled with the aerials and connected to the detector, the two movable members being arranged with a right angle between them.

2168. **M. Jeance.** Wireless Direction Finding Apparatus. (*French Patent* 507344, March 7th, 1919. Published September 10th, 1920.)

A pair of aerial coils have their circuits connected to a reversing switch, whereby they may be connected in series or in opposition to the detector circuit. One coil is turned to its minimum position and by means of the switch the effect of the other coil is added to or subtracted from it. The coils are rotated until equal sounds are heard in both positions of the switch. For further particulars see *British Patent* 158284.*

2169. **J. Robinson** and **H. L. Crowther.** Directive Wireless Signalling. (*British Patent* 161449, April 23rd, 1920. Patent accepted April 14th, 1921.)

Relates to a receiving system for analysing the direction of incoming signals. Two rotatable frame aerials mounted at an angle to each other are connected to the grids of two amplifying valves. The secondary winding of a transformer, the primary of which is connected to a low frequency oscillating source is connected between the grids of the two valves, so that the valves are in operation during the peaks of alternate half oscillations. The required direction of propagation is found by swinging the pair of frame aerials until the combined effect of the received signals produces a pure tone in the telephones. The two aerials are then equally inclined to the direction of the incoming signals.

2170. Absolute Direction Finding with a Loop Aerial. (*Wireless World*, 8, pp. 350—351, August 7th, 1920. *Telegraphen- und Fernsprech-Technik*, 10, p. 30, March, 1921—Abstract.)

Describes a combination of loop and elevated aerial for giving the "sense" indication in D.F. work with a loop aerial.

2171. **M. Latour.** Wireless Direction Finding Systems. (*British Patent* 148950, July 10th, 1920. Convention date December 7th, 1918. Patent not yet accepted.)

A wireless direction finder comprises two frame aerials fixed at an angle to one another and associated with a differential detector, which gives a null effect when the direction of the sending station bisects the angle between the coils. The arrangement may be adapted to the distant control of movable apparatus.

2172. **E. F. Huth.** Wireless Directional Receiving Apparatus. (*British Patent* 149212, July 12th, 1920. Convention date October 25th, 1918. Patent not yet accepted.)

A radiogoniometer apparatus for directive wireless reception and the elimination of undesired signals comprises two or more directive aerials at different angles, and connected to the input side of thermionic valves, the output circuits including the radiogoniometer coils set at the same angles as the aerials.

2173. **J. Erskine-Murray** and **J. Robinson.** Means for Comparing Sounds. (*British Patent* 159601, December 1st, 1919. Patent accepted March 1st, 1921.)

In comparing the intensities of sounds, particularly in wireless direction finding systems, in which the received signal strengths from two coils are to be compared, the sounds are listened to alternately, the alternations being made so rapidly that the sounds cannot be independently distinguished. The alternations may be effected by a rotary commutator, and a pure note is obtained when they are of equal intensity, and a throbbing sound when they are unequal.

2174. **M. Jeance.** Wireless Direction Finding Apparatus. (*British Patent* 158284, April 12th, 1919. Patent accepted February 10th, 1921.)

Two receiving loops at right angles have their circuits connected to a reversing switch so that they may be connected in series or in opposition in the detector circuit.

2175. **Gesellschaft für Drahtlose Telegraphie.** Direction Finding Apparatus. (*British Patent* 147700, July 8th, 1920. Convention date June 3rd, 1918. Patent not yet accepted.)

In a receiver using a rotating loop aerial the capacity of the aerial to earth is augmented to increase the absorption of energy. The receiver is loose coupled to regain the selectivity.

* RADIO REVIEW Abstract No. 2174.

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2176. **E. Bellini.** Electrostatic Coupling. (*British Patent* 145049, June 15th, 1920. Convention date November 4th, 1916. Patent accepted October 7th, 1920.)

An addition to *British Patent* 22879/1914. Details are given of the means of constructing the coupling condensers, and the equations determining their form.

2177. **Gesellschaft für drahtlose Telegraphie.** Directive Wireless Reception. (*British Patent* 148530, July 10th, 1920. Convention date June 18th, 1918. Patent not yet accepted.)

A combination of loop and elevated aerial in which the latter screens the loop in one direction. Similar arrangements may be used for lessening interference from a transmitter in a given direction.

2178. **J. Robinson.** Wireless Direction Finding Apparatus. (*French Patent* 508119, January 3rd, 1920. Published October 2nd, 1920.)

The specification describes a wireless direction finder in which a directive system is combined with a non-directive system so that the intensity of minimum signals observed is not zero as in the case when the directive system alone is used. See also *British Patent* 134342. (RADIO REVIEW Abstract No. 810, September, 1920.)

(S.) Distant Control by Wireless.

2179. **J. Bethenod.** Wireless Control of Distant Apparatus. (*British Patent* 143456, September 9th, 1919. Patent accepted May 27th, 1920.)

In order to maintain a distant movable object on its correct course, the moving vehicle (or vessel, aircraft, etc.) is provided with a radio transmitter, and two D.F. receiving aerials are arranged to receive equal strength signals when the vessel is on its correct course. If the received signal strengths are unequal a correcting impulse is automatically transmitted from a central radio station connected by land lines with the two receivers.

2180. **J. H. Hammond.** Wireless Control of Distant Apparatus. (*British Patent* 143581, November 14th, 1917. Convention date September 28th, 1916. Patent accepted June 3rd, 1920.)

To obtain the necessary selectivity and freedom from interference at least three frequencies are employed—the carrier wave frequency, a supersonic modulating frequency, and a lower group frequency which divides the supersonic modulating frequency into low frequency sections or groups. The circuits of the receiver should be syntonised to these three frequencies, and include a mercury vapour valve relay controlling a slow acting relay for operating the pneumatic valves of the driving or controlling mechanism of the dirigible or other moving vessel.

Details are given of the spark gap apparatus for producing the desired radiations, and of the slow acting relay mechanism for the receiver.

2181. The Exhibition of the Société Française de Physique. (*Radioélectricité*, 1, p. 548, April, 1921.)

A short account of some exhibits which included some distant control apparatus.

2182. **W. W. Conners.** Wireless Control of Distant Apparatus. (*British Patent* 144622, May 25th, 1920. Convention date June 12th, 1919. Patent not yet accepted.)

The specification relates to apparatus controlled by wireless waves for indicating and recording on a chart carried by a moving body the course over which it travels. The apparatus may be adapted to perform many minor functions such as—to record the time certain points are reached, to keep the moving body on a desired course, to indicate and regulate its speed, to record the distance it travels, etc.

2183. **J. H. Hammond.** Wireless Signalling Systems. (*British Patent* 158200, March 8th, 1918. Convention date March 17th, 1917. Patent not yet accepted.)

A selective wireless system for distant control consists of a transmitter emitting waves and wave groups, and a receiving system comprising circuits tuned to the wave and wave group frequencies respectively, circuits tuned to a beat frequency (derived from a local heterodyne) and a mercury vapour detector. The detector circuit includes a high-frequency alternator and a telephone receiver or the relay controlling the apparatus to be directed.

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2184. **E. C. Hanson.** Wireless Steering of Torpedoes and Submarine Vessels. (*British Patents* 154532 and 154533, November 23rd, 1920. Convention dates June 4th, 1918, and February 20th, 1919, respectively. Patents not yet accepted.)

(T.) High-frequency Wire Telegraphy and Telephony.

2185. **G. A. Campbell (Western Electric Company).** Electric Filter Circuits. (*British Patent* 142115, April 21st, 1920. Convention date July 15th, 1915. Patent accepted January 13th, 1921.)

Relates to filter circuits of a general type to permit of the passage of one or two bands of frequencies and the suppression of all others. The filters described in Patent No. 135635 * constitute a special case of this general form, which consists of a series of units consisting of impedances in series with (usually a capacity in series with an inductance) and of impedances in shunt to the lines (usually a capacity in parallel with an inductance). A general mathematical investigation is given to enable the dimensions of the impedances to be calculated to pass any given bands of frequencies. By suppressing one or more of the series or shunt impedances the simplified case above referred to is obtained.

2186. **H. J. Vennes (Western Electric Company).** Generating Harmonics of Electric Oscillations. (*British Patent* 142474, April 27th, 1920. Convention date April 28th, 1919, Patent accepted December 30th, 1920.)

For the generation of currents of frequencies which are harmonics of a given supply frequency, a resistance is joined in the plate circuit of a three-electrode valve of a value large compared with the internal impedance of the valve, so as to distort its characteristic curve. A circuit is given suitable for the generation of such harmonics. It consists of a valve having a high resistance in its plate circuit, and with its grid supplied from the source of given frequency, a shunt rejector circuit being added to by-pass all frequencies other than the fundamental. The output circuit of the valve which introduces the distortion may be joined to a second amplifying valve before attachment to the final output circuit. Additional filtering out of the fundamental frequency may be obtained on the output side of the distorting valve by the use of appropriate shunting impedances.

2187. **Western Electric Company.** Generating Electric Oscillations. (*British Patent* 142571, February 12th, 1919. Patent accepted May 12th, 1921.)

In an arrangement primarily intended for multiplex high-frequency wire telegraphy or telephony, the currents of different frequencies are generated by introducing harmonics into a supply source of given frequency by means of a valve operated near the saturation point. The various harmonics may be separated by appropriate filters.†

2188. **P. R. Coursey.** Wired Wireless Transmission. (*Wireless World*, 8, pp. 699—701, January 8th, 1921. *Electrical World*, 77, p. 611, March 12th, 1921—Abstract.)

A general summary of the methods of communicating by high-frequency currents along wires, and in particular describing the methods used in the German high-frequency telephone exchanges.

2189. **C. A. Culver.** Guided-wave Telephony. (*Journal of the Franklin Institute*, 191, pp. 301—328, March, 1921. *Electrical World*, 77, p. 781, April 2nd, 1921—Abstract. *Technical Review*, p. 144, May 31st, 1921—Abstract.)

A short summary of Gen. Squier's contribution to the development of high-frequency wire telephony, is followed by sections devoted to the principles involved in this method of communication, and the applications of the three-electrode tube, including a consideration of the various methods of modulation, and of the number of separate channels that can be worked on a given line. The use of a modulation circuit equivalent to the " quiescent-aerial " radiotelephone transmitter, in which the generation of high-frequency oscillations only takes place when the microphone is spoken to, is also discussed in its bearing on the number of channels that can be worked simultaneously. Six separate channels can at present be used between 15,000 ~ and 500,000 ~, using different carrier frequencies for each direction of

* RADIO REVIEW Abstract No. 523, July, 1920.

† Compare also RADIO REVIEW Abstracts Nos. 2185 and 2186.

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each conversation. Sections are also devoted to attenuation and efficiency and the power required for various ranges.

2190. Multiplex Telegraphy and Telephony with High-frequency Currents along Wires. (*Schweizerische Bauzeitung*, 76, pp. 230—232, November 13th, 1920. *Revue Générale de l'Électricité* 9, p. 59D, February 19th, 1921—Abstract.)

A summary of the development of high-frequency communication along wires, and a discussion of the economies possible by its use.

2191. **R. D. Duncan.** Recent Attainments in Wired Radio. (*Journal of the Franklin Institute*, 191, pp. 23—56, January, 1921. *Telegraph and Telephone Age*, 39, pp. 74—76, February 16th; pp. 98—101, March 1st; pp. 122—124, March 16th; pp. 146—147, April 1st; pp. 173—174, April 16th; pp. 196—197, May 1st, 1921. *Electrical World*, 77, p. 498, February 26th, 1921—Abstract. *Nature*, 107, p. 87, March 17th, 1921—Abstract. *Revue Générale de l'Électricité*, 9, p. 167D, May 21st, 1921—Abstract. *Radio News*, 2, pp. 592—593, and 640, March, 1921—Abstract. *Technical Review*, 9, p. 172, June 14th, 1921—Abstract. *Science Abstracts*, 24B, p. 312, Abstract No. 635, June 30th, 1921—Abstract.)

A short summary is given of some of the most noteworthy historical developments of "wired radio," followed by a more complete account of later work carried out on the lines of the New York Central Railroad Company. Several illustrations of the apparatus are included, with circuit diagrams and oscillograms of the modulation. A section of the paper is devoted to the mathematical theory of the propagation of high-frequency currents along telephone lines, and many measurements of line constants, at high frequencies, are given in the form of curves.

2192. **G. A. Beauvais.** High-frequency Signalling. (*French Patent* 503943, December 14th, 1917. Published June 21st, 1920.)

The specification describes broadly the method of signalling along conductors by means of high-frequency currents, in which three-electrode tubes are employed.

2193. **J. B. Pomey.** Submarine Telegraphic Transmission. (*L'Électricien*, 52, pp. 31—33, January 15th; pp. 202—205, May 1st, 1921.)

Deals with Squier's and other arrangements of multiplex high-frequency telegraphy along wires and cables.

2194. **B. W. Kendall (Western Electric Company).** Repeaters for Multiplex Signalling Systems. (*British Patent* 153563, August 18th, 1920. Convention date August 31st, 1919.)

Describes an arrangement of two-way valve repeater having a substantially rectilinear characteristic so as to enable it to amplify modulated carrier currents of different frequencies in multiplex high-frequency wire telephony.

2195. **Western Electric Company (U.S.A.).** Signalling by Electric Oscillations in Line Wires. (*British Patent* 153672, August 12th, 1919. Patent accepted November 12th, 1920.)

The specification relates to multiplex systems in which the speech currents are transmitted as modulations of high-frequency carrier currents. Carrier currents of different frequencies are supplied to balanced valve modulators arranged so as to suppress unmodulated carrier currents while transmitting carrier currents which have been modulated. Filter circuits are used between the transmitters and the line wires.

2196. **Gesellschaft für drahtlose Telegraphie.** Telephone Systems. (*British Patent* 161573, April 11th, 1921. Convention date April 12th, 1920. Patent not yet accepted.)

The exchange arrangements for trunk line high-frequency wire telephony are described.

2197. **E. F. Huth.** Telephone Systems. (*British Patent* 161577, April 12th, 1921. Convention date April 12th, 1920. Patent not yet accepted.)

Relates to an arrangement for high-frequency telephony along power lines in which the energy for the plate circuits of the valves is derived from the same power supply. The same valve can be used for both transmission and reception by means of simple change-over switches.

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2198. **P. Gehne.** Wireless Telephony and High-frequency Telephony along Wires. *Zeitschrift für deutsche physikalische und chemische Unterr.*, 33, p. 68, 1920.)

2199. **B. Rosenbaum** and **S. Loewe** (E. F. Huth Gesellschaft). Telegraphy and Telephony. (*British Patent* 149191, July 12th, 1920. Convention date September 15th, 1915. Patent not yet accepted.)

Relates to high-frequency telephonic and telegraphic systems with or without wires. Spark gap apparatus of supersonic group frequency, or thermionic valves may be used as sources of the high-frequency current.

2200. **Gesellschaft für drahtlose Telegraphie.** High-frequency Telephony. (*British Patent* 156655, January 6th, 1921. Convention date January 7th, 1920. Patent not yet accepted.)

In a high-frequency wire telephone system means are provided for preventing injurious coupling between the circuits of the oscillating valve and the detecting and receiving valve. A species of " bridge " connection is used for this purpose.

2201. **Gesellschaft für drahtlose Telegraphie.** High-frequency Line Telegraphy. (*British Patent* 158198, January 14th, 1921. Convention date January 16th, 1920. Patent not yet accepted.)

Relates to means of transmitting buzzer calling signals over a high-frequency wire telephone circuit.

2202. **Gesellschaft für drahtlose Telegraphie.** High-frequency Signalling. (*British Patent* 147464, July 7th, 1920. Convention date May 28th, 1919. Patent not yet accepted.)

Relates to means for bridging over a shunting apparatus connected to power mains or telephone systems the lines of which are used for high frequency telegraphy or telephony.

2203. **Gesellschaft für drahtlose Telegraphie.** Wave Telephony. (*British Patent* 147699, July 8th, 1920. Convention date January 17th, 1919. Patent not yet accepted.)

A coupling is provided between the transmitter and adjacent receiver to eliminate interference in two-way high-frequency telephony.

2204. **Gesellschaft für drahtlose Telegraphie.** High-frequency Telegraphy and Telephony. (*British Patent* 154884, October 22nd, 1920. Convention date December 1st, 1919. Patent not yet accepted.)

The stations are capacitatively coupled to the lines at distances from the ends equal to a quarter of the wavelength, so that the electrical portion of the E.M. field is used for the coupling.

2205. **Gesellschaft für drahtlose Telegraphie.** Multiplex High-frequency Telephony. (*British Patent* 148444, July 10th, 1920. Convention date May 27th, 1919. Patent not yet accepted.)

(U.) Miscellaneous Methods of Communication.

(1.) BY LIGHT RAYS.

2206. **A. M. McMahon.** The Action of Roentgen and Gamma Radiations upon the Electrical Conductivity of Selenium Crystals. (*Physical Review*, 16, pp. 558—564, December, 1920. *Science Abstracts*, 24A, p. 137, Abstract No. 304, February 28th, 1921—Abstract.)

2207. **Miss E. F. Seiler.** Colour Sensitiveness of Photoelectric Cells. (*Astrophysical Journal*, 52, pp. 129—153, October, 1920. *Science Abstracts*, 24A, pp. 136—137, Abstract No. 302, February 28th, 1921—Abstract. *Physical Review* 15, p. 550, June, 1920—Abstract.)

Deals with experiments on the sensitiveness of photoelectric cells for light of various colours. Many different types of cells were experimented with containing a variety of alkaline hydrides.

2208. **L. Ancell.** Selenium and its Applications. (*L'Elettrotecnica*, 8, pp. 201—203, March 25th, 1921.)

2209. **T. W. Case.** New Strontium and Barium Photoelectric Cells. (*Physical Review*, 17, pp. 398—399, March, 1921.)

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2210. **E. Furet.** Telegraphy by Light Rays. (*French Patent* 506757, November 29th, 1919. Published August 30th, 1920.)
The specification describes a method of communicating with a train.

2211. **L. A. Charbonneau.** Signalling by Infra-red Rays. (*British Patent* 146138, June 23rd, 1920. Convention date February 11th, 1918. Patent not yet accepted.)
The infra-red rays are used to wipe out the phosphorescence of certain substances (such as zinc sulphide) at the receiver.

2212. **W. Scheffer** and **A. Heibemann.** Observing and Signalling through Fog. (*British Patent* 157399, January 10th, 1921. Convention date December 8th, 1916. Patent not yet accepted.)
Objects to be observed through fog are illuminated by red or long-wave light and red or long-wave searchlights are used for signalling, the dispersion of light by fog being greater the shorter the wavelength of the light.

2213. **C. C. Murdoch.** A Study of the Photo-active Electrolytic Cell, Platinum—Rhodamine B—Platinum. (*Physical Review*, 17, pp. 626—647, May, 1921.)

2214. **M. Larigaldi.** Recent Applications of Infra-red Radiations. (*Bulletin de la Société Française des Électriciens*, 1, (4th Series) pp. 185—189, April, 1921.)
Discusses their uses for signalling purposes and when associated with a valve amplifier and tikker for reception and also deals with their uses at sea for the detection of shipwrecks.

2. Books.

CONTINUOUS WAVE WIRELESS TELEGRAPHY. Vol. I. By W. H. Eccles, D.Sc. (London: *The Wireless Press, Ltd.* 1921. Pp. vii + 407. $8\frac{1}{2}'' \times 5\frac{1}{2}''$. Price 25*s.* net.)

The preliminary announcement of Professor Eccles' book was made so many months ago that one recently began to doubt whether it would ever appear. The publication now, however, happens to coincide with a pause in the development of the subject, and because of this and also because of the necessary incompleteness of any book on wireless published during war-time conditions, one guesses that the volumes of this treatise will not have suffered for the delay.

To a certain extent the volume is somewhat of a surprise in that it is wholly introductory; that is to say the subject proper of Continuous Wave Telegraphy is not yet reached. Dr. Eccles deals mainly with difficulties which must be satisfactorily surmounted before the main problem can be attacked. Thus two-thirds of the volume are devoted to the fundamental principles of electromagnetism and the rest to the physics of ionic tubes. We hope that this means that the treatment of the whole subject is going to be on the same comprehensive scale, though one must admit that an author who can count on his readers possessing such a groundwork of fundamental theory as is developed in this first volume will find brevity and pertinence possible in his later ones.

The first four chapters contain a short sketch of the history of the subject followed by a very thorough treatment of electrostatics, electrodynamics and alternating current theory. It is very difficult to produce something fresh in a treatment of the elementary facts of electricity, yet Professor Eccles has managed to do so. As a typical example we might cite the novel proof on page 34, in which it is shown that the lateral pressure of a tube of electric or magnetic force is equal to the longitudinal tension. We have in mind more than one proof of this theorem in standard text-books that weary the student unnecessarily.

In the treatment of electromagnetism the author thinks it wise "to follow Oliver Heaviside's and J. J. Thomson's methods of combining the purely physical intuition of Faraday with the mathematical reasoning of Maxwell." Thus the treatment throughout is based on J. J. Thomson's assumption that the magnetic effects of a current are due to the motion of Faraday tubes. This point of view was first developed comprehensively by J. J. Thomson in his supplementary volume to Maxwell's Treatise, and also in his "Elements of the Mathematical Theory of Electricity and Magnetism." It is the only satisfactory treatment possible if, as throughout the present volume, the physics is counted as being of greater importance than the mathematical processes.

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The subject of self and mutual inductance is mainly developed from a consideration of the energy in the field of a current, though Neumann's formula for the mutual linkages of two circuits is also given. The calculation of the inductance of certain simple geometrical forms is, however, carried out with the simplest mathematics.

The treatment of the second law of electromagnetism is again based on the conception that the magnetic field is due to moving Faraday tubes, but here the effective inertia of the tubes becomes of importance and we are concerned with the electric forces necessary for accelerating and retarding the motion of the tubes. This portion of the book closes with a section on units in which the author makes the suggestion that as names have already been given to the principal practical units (*e.g.*, farad) we might consider this term as generic and shorten our usual expression " electromagnetic unit of capacity " to " emfarad " and so on.

The treatment of alternating currents and oscillations is throughout a graphical one, much use being made of crank or Argand diagrams. The section on harmonics leads naturally to a practical discussion of Fourier analysis, the whole of which is summarised in a very useful paragraph which also includes rules for the rough analysis of a periodic curve by inspection. The mathematical treatment of oscillatory circuits includes an analysis of almost every combination of inductance, capacity, and resistance than can be conceived, but, by the use of Heaviside's " resistance operators " the mathematical formula are never allowed to become unwieldy.

The section on ionic tubes is the most exhaustive discussion of the physics of the triode that has yet appeared in English. Though much has been written on this subject the author has again something fresh and new (*e.g.*, in the section on soft tubes). But probably the most interesting portion of this chapter is that dealing with the theory of the action of the control electrode. So very much work has been done using experimentally obtained characteristics that it is refreshing to find an attempt to interpret these curves in terms of known physical laws. The case of the planar triode is of course satisfactorily dealt with in Maxwell's Treatise, but the author prefers to deduce an expression for the voltage factor from first principles, arriving at a result which is practically identical with Maxwell's. What one misses here is a definite statement as to what the voltage factor really is physically. Thus an interpretation of one of the equations here used shows that the voltage factor is taken as the ratio of the difference of potential between the anode and the mid-point of one of the grid spaces to the difference of potential between the mid-point previously mentioned and the grid wire. It is not, however, difficult to show that the value of the voltage factor here used is really equal to the ratio of the number of lines of force ending on the grid to the number ending on the anode when the two electrodes are maintained at the same potential with respect to the filament. This alternative definition emphasises the superiority of the grid over the anode for use in controlling the field strength near the cathode in an amplifying tube.

In the section on grid currents some quite new material is introduced. The question as to how the total thermionic current is divided between the two positive electrodes is a matter of great interest and one very much regrets that considerations of space prevented Professor Eccles from developing in full the formula he gives for this distribution. There still appears to be much work necessary before the relations between grid and anode currents and the electrode potentials are fully elucidated, as secondary emission appears to play quite an important part at relatively low potentials.

The volume closes with a very exhaustive account of the many methods now in use for measuring the various parameters of triodes.

The index is admirable in every way and adds greatly to the value of the book. There are a few errors in the text, but we understand that a table of errata is soon to be published.

E. V. APPLETON.

RELATIVITY, THE ELECTRON THEORY AND GRAVITATION. By E. Cunningham, M.A. (London: *Longmans, Green & Co.* Second Edition, 1921. Pp. vii + 148. $8\frac{3}{4}'' \times 6''$. Price 10*s.* 6*d.* net.)

The publication of this, the second edition of " Relativity and the Electron Theory," makes a valuable addition to the literature of these subjects. The original work was devoted to a consideration of both theories (Theory of Relativity and the Electron Theory) and of their mutual consequences, and in the new edition the matter has been much added to, and the treatment improved by the inclusion of later work.

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The consideration given to the subject now goes beyond Einstein, and shows that his Generalised Relativity Theory is by no means the last word on the subject. The final chapter of the book gives this further generalisation, and includes Weyl's theory of Electricity, and makes it clear that the laws of Nature do not supply us with an absolute criterion of equality of intervals of space and time, except of course the criterion of coincidence. Weyl's theory provides for electricity as natural a place as that accorded to gravitation in Einstein's theory, with the result that gravitation and electricity rank together as two fundamental properties of matter, forming together the basis of all natural systems of measurement.

The book has been approximately doubled in size by the inclusion of this new matter, and in spite of its somewhat mathematical appearance, provides very interesting reading.

P. R. C.

Correction.

CURRENT SUPPRESSION BY MEANS OF PARALLEL RESONANCE. By H. G. CORDES.

The following corrections were received from the author too late for inclusion in the article which was published in the last issue :—

Page 362, *equation* (20), *should read :*

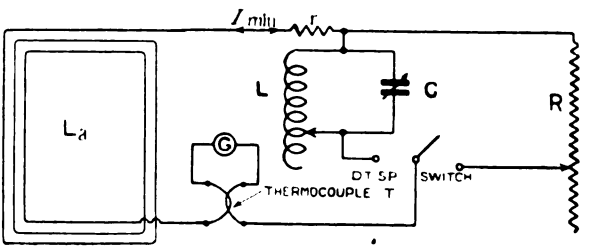
$$U = (\omega^2 L_x C_x - 1)\left[\frac{1}{C_x} + \frac{\omega^2 L_z C_z - 1}{\omega^2 L_x C_x C_z + \omega^2 L_z C_z C_y - (C_y + C_z)}\right]\frac{1}{\omega} \quad . \quad (20)$$

Page 369, *line* 12, *for* " one form of rate of change " *read* " a negative rate of change . . ."

The lower half of p. 369, *and the first four lines of p.* 370, *including Fig.* 7, *should read as follows :—*

Fig. 7 shows a wave tester comprising a suppressor LC, a coil aerial L_a, a thermocouple T, a galvanometer G, a coil aerial circuit resistance r, a non-inductive resistance R and a throw-over switch.

The wave of the transmitter to be tested is impressed upon L_a. Maximum suppressive impedance is indicated by $I_{(min.)}$ through T. The value of R is made equal to the maximum



suppressive impedance of LC ; this value of R is determined by throwing the switch S to the right without changing the value of $I_{(min.)}$ The resistance r renders the coil aerial circuit aperiodic when the maximum suppressive impedance has an effective negative reactive component.

The quality of a wave can be expressed numerically as the ratio of R for the tested wave to R for a sine wave of constant frequency and constant amplitude. The latter value of R may be either measured with a sine wave or calculated from the constants of the suppressor by equation (16). The only part of this arrangement which would require standardisation is the suppressor circuit.

Suppressive impedance as a standard has the advantage of being a comparatively large quantity and neither potential nor current values need be determined. Suppressive impedance is decreased when the wave has a decrement, an increment or a harmonic. Sharpness of resonance is reduced by a harmonic in selective suppression but not in selective reception; harmonics cause interference in selective reception.

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VOL. II **SEPTEMBER, 1921** NO. 9

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PROFESSOR G. W. O. HOWE, D.Sc., M.I.E.E.
Assistant Editor:
PHILIP R. COURSEY, B.Sc., F.Inst.P., A.M.I.E.E.

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RADIO REVIEW

VOL. II SEPTEMBER, 1921 NO. 9

Harmonics and Normal Modes of Vibration.

By THE EDITOR.

In his recent paper before the Wireless Section of the Institution of Electrical Engineers, Professor Townsend emphasised the distinction between these two entirely different things. They are so often confused that we feel justified in returning to the matter. If an oscillatory system such as an aerial with distributed inductance and capacity has an E.M.F. induced in it by the current in a neighbouring circuit, and the frequency of this current be varied, a number of frequencies will be found for which the current produced in the aerial is abnormally large. Although it is usual to speak of these frequencies as the third, fifth, etc., harmonics, they do not bear any such simple relation to the fundamental frequency. It should be noted, moreover, that if the source be a pure sine wave of any given frequency, an oscillation of this frequency only will be set up in the aerial. The frequencies at which abnormal response is found in the aerial correspond to its normal modes of vibration, or in other words, correspond to stationary wave distributions having a current node at the top and a potential node at the base.

If such an aerial were coupled to a radio frequency alternator the E.M.F. curve of which contained a pronounced third harmonic the current set up in the aerial would consist of a fundamental and a third harmonic, that is, one having exactly three times the fundamental frequency. This would not, in general, correspond to the normal mode of vibration sometimes called the third harmonic of the aerial. If this were not so, the wave form of the aerial current would undergo gradual changes.

The problem is not so obvious when the source is an arc or valve transmitter, the frequency of which is controlled by the characteristics of the aerial. If, however, it be assumed that each oscillation is of the same wave shape—depending on the aerial and on the arc—all frequencies other than exact harmonics of the fundamental are impossible.

It would be of interest to know whether, in an arc transmitter with tuning inductance between the arc and the aerial and with the arc itself shunted with a condenser as is now sometimes the case, any trace can be found of one of the normal modes of vibration other than the fundamental with its true harmonics. This cannot be tested on a dummy aerial with concentrated capacity, but only on a system having distributed capacity.

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The multivibrator of Abraham and Bloch is said to give a wave form which is rich in harmonics. What is meant by this statement? If a circuit consisting of a battery and a non-inductive resistance is closed for a very short time, say a millionth of a second, with great regularity a thousand times per second, the diagram showing the current plotted to a time base would consist of a number of narrow rectangular humps widely separated from each other (Fig. 1).

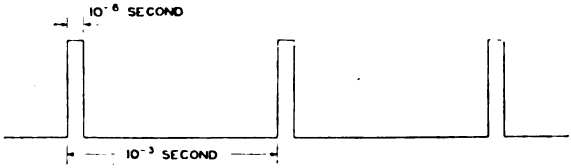

FIG. 1.

Now this is a wave form very rich in harmonics. Although physically there is nothing to suggest any frequency other than 1,000, the wave form could be analysed by Fourier's theorem into a steady current, a fundamental sine wave with a frequency of 1,000 and an infinite number of harmonics both odd and even. It is well to recognise that the currents obtained from oscillating valve systems are only rich in harmonics in this sense.

In the case considered above a wavemeter tuned to a frequency of 20,000 would receive an impulse every twenty oscillations and then be left to itself for a thousandth of a second. That it is being acted upon the whole time by an infinite number of currents of different harmonic frequencies is really nothing more than a mathematical fiction.

When one looks at the wave form of the voltage of an alternator and recognises clearly a ripple of a definite frequency one sees that the harmonic is present in a more real physical sense than in the above diagram. Mathematically, however, the difference is due to the absence from the voltage wave of the infinite number of harmonics which go to make up the diagram given above.

A Method of Measuring the Specific Inductive Capacity of Air.*

By E. W. B. GILL, M.A., B.Sc.

The accurate comparison of the wavelength of two circuits enables various measurements of capacity, inductance, etc., to be made, and one of the most convenient methods of estimating the equality of wavelength of two circuits is by the well-known "beat method" of reception.

* Received March 3rd, 1921.

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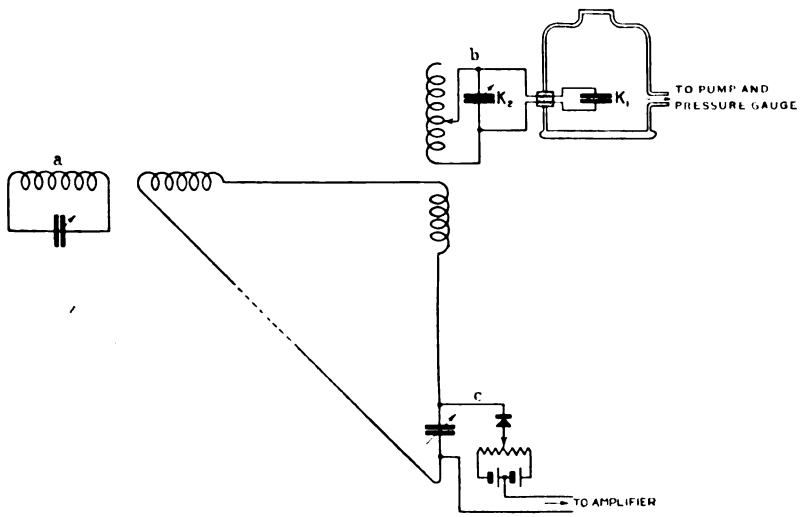
For the very greatest accuracy however a difficulty arises which can be seen by considering the beat method more closely. If two undamped waves of wavelength λ_1 λ_2 and frequencies n_1 n_2 are received simultaneously on a third circuit the frequency of the audible note heard is $n_1 - n_2$. Thus if λ_2 is fixed and λ_1 is varied from a value slightly larger than λ_2 to one slightly less the note heard goes from high to low, disappears over a range, reappears again and goes from low to high. The equality of wavelength occurs at the middle point of this inaudible range, and this cannot be accurately found owing to the great difficulty of telling where the sound dies away and reappears. An alternative is to find λ_1 in terms of λ_2 for some point of the audible range by estimating the frequency of the beat note $n_1 - n_2$ (this was virtually the method employed by Pungs and Preuner—*Physikalische Zeitschrift*, December, 1919) which at once gives $\lambda_1 - \lambda_2$.

The determination of a note frequency is however not easy and in any case involves extra apparatus and for this reason it was thought worth while to publish a simple method of producing the desired result and capable of very considerable accuracy.

In this method there are various ways of arranging the apparatus but only the actual one used will be described; the object of the research being to measure the specific inductive capacity of air, or other gases.

Arrangement of Apparatus.—Two entirely separate valve transmitting circuits of the ordinary type were set up some distance from one another, these circuits being referred to in what follows as **a** and **b**. A third circuit **c** was used as a receiver its inductance consisting of two coils in series, the first coupled fairly tightly to **a** and the second to **b**. All the



a and **b** = Transmitters (valves, reaction coils, batteries, etc., not shown).
c = Crystal Receiver.

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rest of this circuit except the coils and their leads was removed as far as conveniently possible from **a** and **b**.

To prevent any chance of the circuit **c** generating an oscillation no valves were used in it but only a carborundum crystal, though probably this was an excess of precaution. (Later a low-frequency amplifier was used after the crystal.) This arrangement of apparatus fulfils the first requisite for accurate work that the experimenter should be some distance from the circuits **a** and **b** as any near movement affects their wavelength; as it is, wearing the telephones puts a variable earth on circuit **c** which affects **a** and **b** through the coupling coils and it is therefore better not to wear the telephones but to make the signals sufficiently loud by a L.F. amplifier to be read with the telephones on the table.

Effects Observed on Tuning.—If now circuit **a** be put at a certain wavelength, **c** tuned roughly to it, and the tuning of **b** then varied the usual ascending and descending musical scale is heard with the inaudible interval; but instead of the "fringes" of the inaudible interval being indistinct it will be found that as the note gets lower it turns into a rattle of fairly high frequency and if the tuning is continued very slowly the frequency of the rattle rapidly decreases (it can with care be adjusted to give two or three "ticks" a second) disappears and reappears on the other side of the inaudible range giving the same phenomena in the reverse order.

The disappearance of the rattle is very sharply marked and hence instead of the old difficulty of trying to estimate where a sound becomes inaudible we have a very simple and accurate method of telling when the wavelengths of **a** and **b** differ by a definite amount.

The explanation of the preceding effect is not quite clear but it is probably due to the fact that circuits **a** and **b** are coupled through **c** and therefore as **b** is tuned more closely to **a** the interaction between the circuits increases with the result that the oscillations in one circuit (the weaker oscillator) are quenched out and restarted a certain number of times per second, the stopping and starting causing the rattle.

In the actual experiment the circuit **b** had two condensers in parallel K_1 and K_2. K_1 was an ordinary air type parallel plate condenser and was enclosed in a bell jar, the connecting wires passed through a cork waxed to a hole in the jar, from which the air could be removed by a pump. A mercury pressure gauge was also attached to give the pressure.

K_2 was a very small condenser consisting of two coaxial cylinders, the capacity of which could be varied by sliding the inner one in and out. The actual size of this was not required but only difference in capacity for small movements. By always working with the inner one about half way in the *variation* in capacity for a small movement could be calculated from the simple formula as the edge errors will cancel. The calculated variation was 1·1 electrostatic units per centimetre. The inner cylinder was moved backwards and forwards by a screw of twenty turns to the centimetre.

In an actual experiment some particular size of the inductance in **b** was selected. The bell jar was pumped to a low pressure and then **a** was roughly tuned to **b** by the heterodyne method. The final adjustment was made on

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the condenser K_2 till the rattle was just on its disappearing point. Air was then admitted to **a** and it was found that a fresh adjustment of K_2 was necessary to get the rattle to the same disappearing point.

It is evident then, whatever the theory of the rattle, that the circuit **b** must be electrically exactly the same in the two cases, *i.e.*, the change in K_1 must have been equal and opposite to that of K_2. But the change in K_1 is due only to the specific inductive capacity of the extra air admitted, the change in K_2 is calculable and therefore the specific inductive capacity of air can be found.

By choosing different sizes of inductance the specific inductive capacity can be found for various wavelengths, the actual wavelengths used were 920, 1,300, 1,760, 4,000 metres.

Sensitivity of Method.—The disappearance of the rattle was so marked that it could be easily measured to one-quarter of a turn of the screw motion of the condenser K_2. This was equivalent to a movement of $\frac{1}{80}$ of a centimetre of the inner cylinder or to $\frac{1{\cdot}1}{80}$ E.S. units. The condenser K_1 being 2 mmfd = 1,800 E.S. units this is equivalent to a variation of about 1 part in 100,000 of the total capacity (or in wavelengths a variation of one in 50,000 can be measured).

Precautions Necessary.—It was speedily found that in dealing with such small capacity variations any small extraneous capacity would vitiate the results. The chief source of trouble, viz. the operator himself has been already referred to, even when far off it is desirable not to move about much and it was necessary to turn the screw adjusting K_2 by a very long ebonite handle.

Another possible source of error is the movement of the mercury up and down the gauge when the pressure varies if the gauge is anywhere near **b** and the gauge and pump were therefore about 10 feet from **b** and joined to the bell jar by rubber tubing which had previously been cleared of occluded gases.

All these precautions are however unavailing unless one can be certain that an oscillating circuit emits waves which will remain constant to at least 1 part in 50,000. It is not necessary to go through the experiments to ascertain if this was so but the final result was that the only variation of this order was due to the slow heating of the rheostat wires controlling the filament currents and that when these were replaced by more substantial wires with larger cooling surface the oscillating circuits came to an admirable degree of constancy in about five to ten minutes. (The H.T. batteries consisted of small accumulators.)

Calculation of Results.—If the dielectric constant of a vacuum be taken as 1, then over the ranges of temperature and pressure used $K-1$ is proportional to the density, K being the specific inductive capacity of the air. The experiment gives the variation in capacity of a 2 milli-microfarad condenser when the air pressure is reduced from p_1 to p_2, the temperature remaining constant at $\theta°$. But the above law being true it is a simple

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matter to estimate what the capacity change would be if the pressure was reduced by 760 and the temperature was 0°; for it is the above variation multiplied by $\frac{760(273+\theta)}{(p_1-p_2)273}$ and thus the specific inductive capacity of air at 0° and 760 mm pressure is obtained.

The following table gives the results for various wavelengths taking the specific inductive capacity of a vacuum as 1.

They are the means of several consistent experiments and as these were taken over various pressure ranges they incidentally confirm the law $K-1$ is proportional to density.

No particular reliance should be laid on the last figure as it is not claimed that these results are accurate to more than 1 per cent.

Over the wavelengths used therefore there is no reason to suppose that any variation occurs with wavelength. Previous values found however for steady and not alternating fields are given in Kaye and Laby's tables as

Wavelength.	Dielectric Constant.
920 metres	1·000658
1,300 ,,	1·000654
1,760 ,,	1·000654
4,000 ,,	1·000653

1·000586 (at 0°-Klemencic, 1885).
1·000576 (at 20°-Tangl, 1908).

Attempts were made to see if the specific inductive capacity of air could be altered by various methods such as the application of a magnetic field, and the passage of a beam of light but such effects if they exist are a good deal less than 0·1 per cent. as no variation could be detected. The specific inductive capacity was also independent of the electric force over a large range, the oscillating current in **b** being varied from 0·1 to 1·5 amps without any change being detected, thus varying the electric force in the condenser by the factor 15 makes no difference.

My thanks are due to Professor Townsend, F.R.S., in whose laboratory these experiments were conducted.

Notation for Electron Tube Circuits.*

By J. H. DELLINGER,
Physicist, Bureau of Standards.

It has become difficult to read papers on electron tube theory and applications because of the large number of quantities and circuits for which symbols must be used. Naturally there has been considerable diversity in the notation employed. This diversity is not so great, however, but that

* Received January 12th, 1921.

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certain well-defined practices have become common, and it appears possible to establish a reasonably consistent notation which may be employed as a basis for all discussions on electron tubes. While there is no way of avoiding an elaborate and complicated appearance in a set of notation which aims to be useful in all sorts of electron tube discussions, the present paper nevertheless has simplification in mind. Current practice and consistency are retained as far as possible. Only parts of this notation will be used in any one paper or discussion. A number of explanatory notes are given after the definitions below.

e_p, e_g = Instantaneous alternating E.M.F. in plate-filament and grid-filament circuit, respectively. (The term "alternating" has the usual meaning of periodic, with average value zero.)

E_p, E_g = Effective alternating E.M.F. in plate-filament and grid-filament circuit, respectively. (The source of E.M.F. is indicated in Fig. 1 as being inside the tube. The notation is not changed if it is outside the tube, or the sum of E.M.F.'s outside and inside.)

v_p, v_g = Instantaneous alternating voltage between plate and filament, and between grid and filament, respectively. (See Fig. 1.)

V_p, V_g = Effective alternating voltage between plate and filament, and between grid and filament, respectively. (See Fig. 1.)

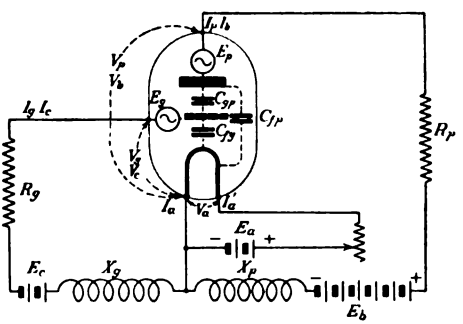

FIG. 1.

i_p, i_g = Instantaneous alternating current to plate and to grid, respectively.

I_p, I_g = Effective alternating current to plate and to grid, respectively.

E_{pm}, E_{gm}, V_{pm}, V_{gm}, I_{pm}, I_{gm} = Maximum values of quantities for which the symbols without the subscript m indicate the effective values.

e_p', e_g', E_p', E_g', v_p', v_g', V_p', V_g', i_p' i_g', I_p', I_g' = Total values of quantities for which the corresponding symbols above indicate the alternating portions. (When a discussion deals with total values extensively and exclusively, the primes may be omitted, in such cases statements being made to keep the reader clear as to which quantities are meant.)

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e_{p_1}, e_{g_1}, E_{p_1}, E_{g_1}, ϵ_{p_1}, ϵ_{g_1}, V_{p_1}, V_{g_1}, i_{p_1}, i_{g_1}, I_{p_1}, I_{g_1} = Fundamental component of alternating quantities indicated by corresponding symbols above. The subscript 1 may be written before instead of after the main symbol if preferred, thus, ${}_1E_p$. The subscripts for other harmonics than the fundamental are similarly treated. (When a discussion deals with the fundamental component extensively and exclusively, the subscript 1 may be omitted, in such cases statements being made to keep the reader clear as to which quantities are meant.)

E_a, E_b, E_c = Direct E.M.F. in filament circuit, plate-filament circuit, and grid-filament circuit, respectively.

V_a, V_b, V_c = Direct voltage between terminals of filament, between plate and filament, and between grid and filament, respectively. (V_b and V_c are measured from that filament terminal to which the tube circuits are connected. This is ordinarily the negative terminal when D.C. is used to heat the filament.)

I_a, I_a' = Direct current through filament at the negative and positive terminals, respectively.

I_b, I_c = Direct current to plate and to grid, respectively. (*Note.*—E_a, E_b, E_c, V_a, V_b, V_c, I_a, I_a', I_b, I_c, are average values or the readings of D.C. instruments. The values of V_b, V_c, I_b, I_c, are in general not the same when alternating current is present as when it is not.)

I = Direct current through filament, with no space current flowing.

V = Direct voltage on filament, with no space current flowing.

I_e = Emission current from filament.

ΔV_b, ΔV_c = Change in direct voltage between filament and plate, and between filament and grid, respectively, when a signal voltage is impressed on the grid of a detector tube.

ΔI_b, ΔI_c = Change in direct current to plate, and to grid, respectively, when a signal voltage is impressed on the grid of a detector tube.

P_a, P_b, P_c = Average power supplied by filament battery, plate battery, and grid battery, or their equivalents, respectively.

P_f, P_p, P_g = Average power consumed by filament, plate, and grid, respectively.

R_p, R_g = Resistance inserted in series with plate and grid, respectively.

L_p, L_g = Inductance inserted in series with plate and grid, respectively.

X_p, X_g = Reactance inserted in series with plate and grid, respectively.

Z_p, Z_g = Impedance inserted in series with plate and grid, respectively.

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r_p, r_g = Internal output resistance and internal input resistance of tube. (The term "internal output resistance" means the resistance in the tube between plate and filament.)

c_g, x_g, z_g = Input capacity, input reactance, and input impedance of tube, respectively.

C_{fg}, C_{gp}, C_{fp} = Individual internal capacities between filament and grid, between grid and plate, and between filament and plate, respectively.

R_o = Resistance of output oscillatory circuit of electron tube acting as a generator. (The output oscillatory circuit is the circuit in which the alternating-current power is produced and may be utilised.)

i_o, I_o = Respectively, instantaneous and effective alternating current in output device or output oscillatory circuit of electron tube acting as a generator. (When the current is not the same in parallel branches of the output oscillatory circuit, or when it is not the same at different points because of distributed capacity, it may be necessary to specify more closely at what point the current is measured.)

e_o, E_o = Respectively, instantaneous and effective alternating E.M.F. in output oscillatory circuit of electron tube acting as a generator. (When the current is not different in different parts of the output oscillatory circuit, $E_o = R_o I_o$.)

P_o = Average power output in output oscillatory circuit of electron tube ($P_o = R_o I_o^2$).

$g_m = \frac{\partial i_p}{\partial v_g}$ = Mutual conductance of grid to plate.

$g_p = \frac{\partial i_p}{\partial v_p}$ = Internal output conductance of tube = $\frac{1}{r_p}$.

$g_n = \frac{\partial i_g}{\partial v_p}$ = Mutual conductance of plate to grid.

$g_g = \frac{\partial i_g}{\partial v_g}$ = Internal input conductance of tube = $\frac{1}{r_g}$.

μ = Amplification coefficient = $\frac{g_m}{g_p}$.

μ_n = Reaction coefficient = $\frac{g_n}{g_g}$.

μ_e = Voltage amplification ratio = $\frac{\partial e_{z_p}}{\partial v_g} = \mu \frac{R_p}{R_p + r_p}$

(where e_{z_p} = instantaneous voltage across Z_p).

μ_i = Current amplification ratio = $\frac{\partial i_{z_p}}{\partial i_g}$.

μ_p = Power amplification ratio.

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It is to be noted that the symbols f, p, g, indicate alternating current values; while symbols a, b, c, indicate direct current values. This convention is already in very extended use.

The use of V rather than E is a matter upon which there will probably not be unanimous agreement. Some writers prefer to use E both for impressed or generated electromotive force and for potential difference (the reading of a voltmeter). When this is done the two cannot be distinguished except by the use of subscripts, and it would be unfortunate to complicate the notation with additional subscripts. The need of the symbol V to designate potential difference is shown by its use by a great many writers on radio and electron tube subjects. Some papers which do not use any distinction in symbols between an impressed E.M.F. and a potential difference are harder to follow on that account.

The notation for harmonics is given (as suggested under definition of e_{p_1}, e_{g_1}, etc.) by adding as a subscript the number giving the order of the harmonic. This may be written either after or before the main symbol, thus—E_{p_5} or ${}_5E_p$. The maximum value of amplitude of a harmonic is indicated by the additional subscript m; but when the discussion deals with the maximum values extensively and exclusively, the m may be omitted, in such cases statements being made to keep the reader clear as to which quantities are meant. For example, $E_{p_{5m}}$ can in such cases be abbreviated to E_{p_5}.

Too much stress cannot be laid upon the need of great care in keeping distinct the instantaneous, effective, maximum, total, total alternating, and the fundamental (or first harmonic) values of the various quantities. The same symbol has been used for all of these in the writings of various authors. This makes it difficult to read papers by different people. The present notation provides separate symbols for all these but avoids cumbersomeness, providing that the special subscripts may be dropped in cases where there would be no confusion. Writers in particular branches of the electron tube field may, on first thought, deny that all of these quantities need to be provided for. Their necessity is apparent, however, when one considers all of the various types of discussion which are being published. The complete symbols for these various values and the symbols to which they may be abbreviated are shown in the following tabulation, for grid current.

The symbols I, V, are used when considering the characteristics of the filament purely as a filament. They are probably of use only in efficiency studies on tubes.

The definitions of g_m, g_p, g_n, g_g are in accordance with definitions given by E. V. Appleton in the RADIO REVIEW, Vol. 1, p. 368, April, 1920.

The n used in the symbol g_n is arbitrarily chosen—simply suggested by the symbol m in g_m. Similarly, the use of n in μ_n is simply by analogy in the use of n in g_n.

The symbol μ_o has sometimes been used for amplification coefficient. It seems better to use the simpler symbol μ for this quantity which is one of

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		Total.	Alternating part of Total.	Fundamental Component*	Harmonics (5th, for example*).
Complete Notation	Instantaneous	i_g'	i_g	i_{g_1}	i_{g_5}
	Effective	I_g'	I_g	I_{g_1}	I_{g_5}
	Maximum	I_{g_m}'	I_{g_m}	$I_{g_{1m}}$	$I_{g_{5m}}$
Abbreviated Notation	Instantaneous	i_g	i_g	i_g	i_{g_5}
	Effective	I_g	I_g	I_g	I_{g_5}
	Maximum	I_{g_m}	I_{g_m}	I_{g_m} or I_{g_1}	I_{g_5}

the principal fundamental properties of the tube, and to use subscripts upon the μ for related ratios.

It will be found necessary to supplement this notation by the adoption of additional conventions for certain kinds of discussions. This will be necessary, for example, in diagrams having many tubes, in some cases of parallel power supply, in plate or grid circuits having sources of E.M.F. both inside and outside the tube, and in the case of coexistence of conductive and capacitive current flow in the tube. In most of these cases additional subscripts will be necessary.

Washington, D.C., U.S.A.,
December 8th, 1920.

Clifden.

By H. J. ROUND,
Marconi Research Department.

The old spark transmitter at Clifden, which has been used for the Canadian wireless service for some years, has never been very exactly described. Figures, therefore, giving a few of the constants of the circuits will be of value as they will enable a comparison to be made with those of the valve transmitter now operating there.

The antenna has an effective average height of about 100 feet and is supported on wooden masts varying from 180 to 220 feet.

The length is about 2,500 feet, the average breadth about 1,200 feet, and

* The subscript denoting the order of the harmonic may be put in front of the main symbol if desired, thus ${}_1i_g$, ${}_5I_{gm}$.

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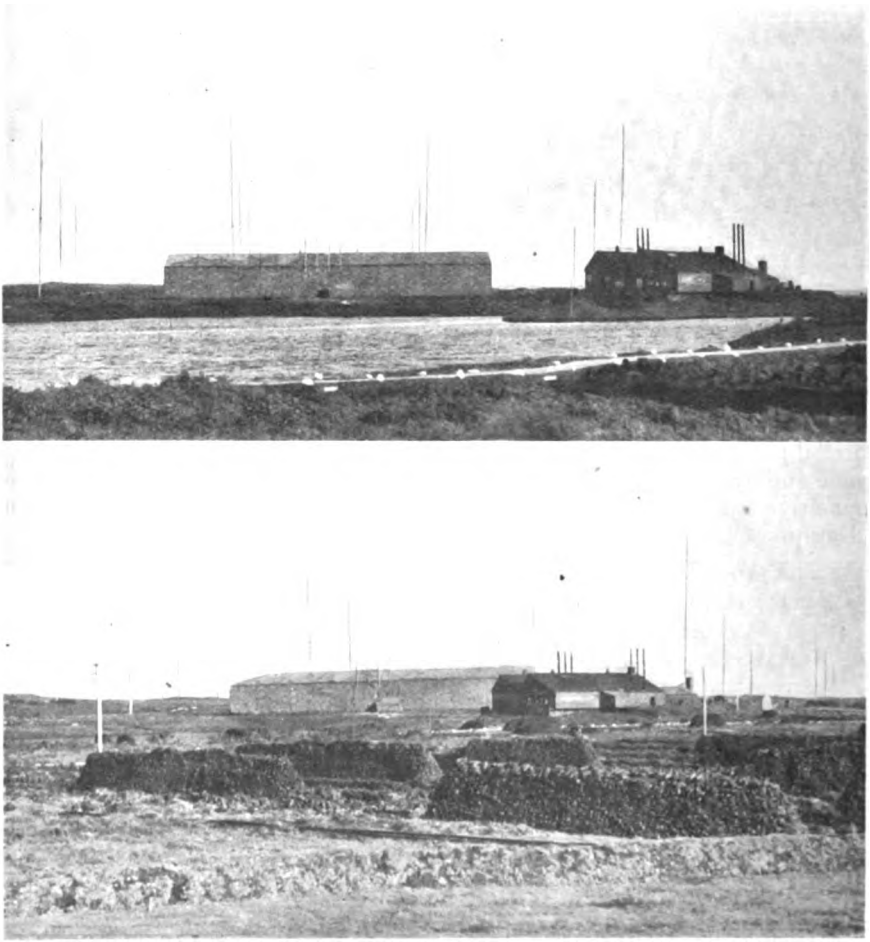
the number of wires is 32. The capacity is approximately 0·035 microfarad.

The aerial resistance, using the old earth plates, was about 4·5 ohms at 5,700 metres. In comparison with many modern aerials it will be seen that



Two Views of Clifden Radio Station.

the effective height is extremely small and also that the resistance is very considerably greater than modern practice will allow.

The primary spark circuit has a logarithmic decrement of about 0·06 per complete period, so that the loss in the primary circuit is not great. The

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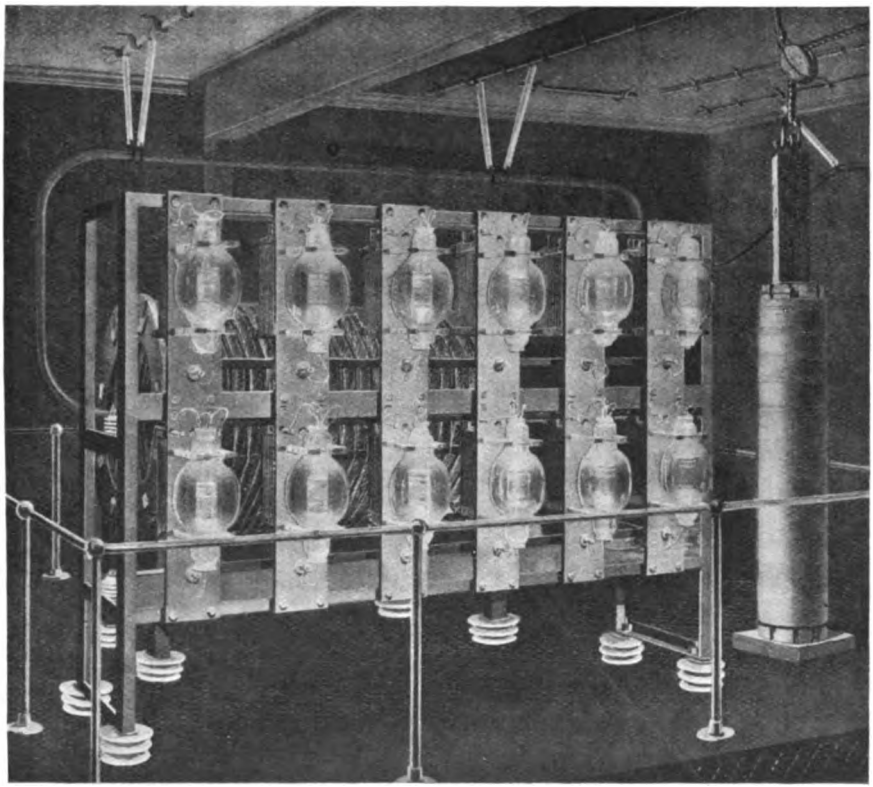
coupling value is about 1 per cent. An input of 80 to 100 kW from the high tension D.C. machines at 10,000 volts gives about 100 amperes in the antenna. This power can be increased up to about 150 kW if necessary.

The efficiency from input primary circuit power to the aerial power is thus about 50 per cent.—but the radiated power is only about 1 per cent. owing to the low effective height and high aerial resistance. This was obviously a place for great improvement.

Actually the total radiation may be considered larger if radiation in direc-



The New Valve Transmitting Apparatus at Clifden.

tions other than that of normal propagation were considered—but this would seldom be of advantage at the receiving end.

A counterpoise earth of the new type, called the "Earth Screen," was erected early last year and the actual resistance of the aerial has now been reduced to 0·6 ohm including the loading coil, thus bringing the radiation efficiency up to 8 per cent.

It is hoped that the actual efficiency can be raised to 40 per cent. and

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experiments are being continued in this direction. The successful reduction of the aerial resistance to 0·6 ohm decided the introduction of a valve transmitter. Everything else was favourable to the plan. Direct current up to 20,000 volts was available—the aerial had so small a loading coil that very little change in the natural period of the aerial would be expected during high winds. The station also had the advantage that its distance from important short wave stations was sufficiently great to permit of a plain aerial circuit, without the accompanying harmonics causing trouble. This very considerably simplified the arrangements to be made.

The whole of the apparatus for the change from spark to valve working was taken out by passenger train—this was of course necessitated by the difficulties of transport in Ireland, but it is actually a tribute to the simplicity of the change to valves.

A valve panel of 12 Marconi MT2 valves was erected and put into operation. Owing to the shortage of valves, only 9 valves were used in the initial tests and the accompanying figures were obtained with the 9 valves.

CLIFDEN VALVE SET TESTS.

September 12th, 1920.

Resistance of aerial: 0·7 ohm. (This has since been reduced.)

Wavelength = 5,600 m. Nine MT2 valves in use.

Total filament current: 90 amperes at 20 volts.

Valve Feed Current.	Aerial Current.	D.C. Voltage.	Kilowatts.		Efficiency Neglecting Filament Current.
			Feed.	Aerial.	
amps.	amps.				
1·55	117	7,700	11·9	9·6	80·5 per cent.
1·85	140	9,500	17·5	11·3	65 ,,
2·2	165	11,400	25·1	19·1	76 ,,
2·75	200	14,000	38·4	28	73 ,,
3·03	222	15,400	46·7	34	73 ,,
3·3	236	16,800	52·8	39·2	74·2 ,,
3·52	250	18,000	60	43·7	73 ,,

The circuit in use is that shown in Fig. 1. It was found necessary, in order to prevent exceedingly high potentials being produced while signalling, to shunt the signalling keys (which incidentally are the same keys as those used for the spark set) with a high resistance and allow the valve set to oscillate weakly during the spacing sign. The actual spacing current is about one-tenth the signalling current but even this value is complained of

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by Canadian receiving stations and it will have to be considerably reduced in the future.

Except on the comparatively rare occasions when the wind blows directly across the aerial, Clifden's wavelength is exceedingly constant and during several hours working will not show a variation of 1 in 7,000. The usual working current is about 180 amperes.

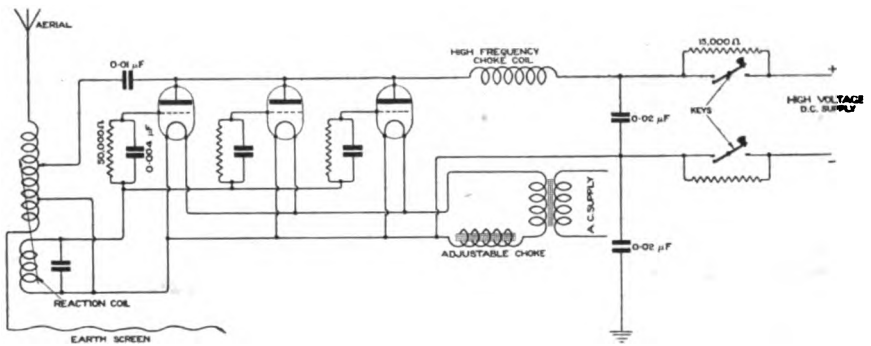

FIG. 1.

Various improvements are being made now and others are projected but at the moment the greatest improvement expected is that due to the installation at Glace Bay of a similar set. The new transmitter at Clifden has now been working successfully for nine months and has provided valuable information and experience in connection with the use of valves under commercial conditions.

The Nature and Nomenclature of Electric Discharges.*

Different types of electric discharge have recently become known which combine in each certain of the characteristics which formerly distinguished the known types of discharge from one another (vacuum discharge, glow discharge, arc, etc.).

For example, in the new neon arc lamp the discharge raises the temperature of points of the cathode to incandescence and vaporisation as in an arc lamp; special means are adopted, however, to prevent the cathode products spreading up the main discharge column in which one has consequently nothing but electrons and ions of the rare gas at a low temperature as in a glow discharge. In another case one has an artificially heated cathode in a gaseous space; in addition to the electrons emitted by the hot cathode, gas ionisation occurs as in glow discharges, which increases the electronic current. Again, the

* From an article by W. Schottky in the *Zeitschrift für technische Physik*, 1, p. 208, September, 1920.

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positive ions on colliding with the cathode can cause a further emission of electrons as in a glow discharge, or they may cause local heating of the cathode and lead to a kind of arc discharge.

Under such circumstances it is a waste of words to argue whether any discharge should be classed under one or other of the formerly distinguished types. To characterise a discharge it is necessary to state as many properties of the phenomenon as can occur independently of one another.

The most obvious proposal appears to be, to state (1) the point at which the discharge originates (cathode, gas or anode) and (2) the nature of the cause which originates it (thermal or otherwise). (3) In addition to this it should be stated whether the energy required to produce the electrons is supplied from the discharge itself or from some external source.

(1) On this plan discharges would be divided into cathodic, anodic, or gas path discharges, together with various combinations of these three depending on the character of the discharge. (2) If in a cathodic discharge, the emission of electrons is due to the heating of the cathode one could call the discharge **cathothermal.** If, however, the electrons are produced at the cathode by the incidence of a wave or of corpuscular radiation or by chemical action, the name **cathodrome** might be applied (δρόμος = a course). In the same way, the production of ions and electrons in the gas path could be called **hodothermal** (ὁδός = path) if due to heat and **hododrome** if due to the incidence of waves or of corpuscles or to chemical action. Although little is known of such processes, the words **anothermal** and **anodrome** could be applied if the discharge originated at the anode.

(3) To distinguish between the cases in which the energy required to produce the electrons is supplied from the discharge itself and those in which it is supplied from a separate source, the words **auto** and **allo** could be introduced.

Whether or not this suggested nomenclature be adopted, it is important that some method be introduced whereby discharges can be correctly characterised.

The following are given as examples of the application of these suggestions :

The neon arc lamp—catautothermal and hodautodrome ;

Ordinary glow discharge—catautodrome and hodautodrome ;

Ordinary thermionic bulbs—catallothermal with more or less hodautodrome, catautodrome and catautothermal.

Discharge in flames—hodallothermal with hodallodrome effects due to chemical reaction in the flame and moreover in some cases hodautodrome effects due to ionisation by collision in strong fields, and catallothermal and anallothermal effects if the electrodes are not cooled. In the carbon arc probably all the " auto " effects will be represented, whilst in the mercury vapour lamp we shall have catautothermal and hodautodrome (no appreciable hodautothermal or anode effects).

Further subdivision would be necessary to characterise completely the nature of the discharge as indicated by the following :—the vapour of the cathode or anode may or may not take an appreciable part in the discharge ; the relation between mean free path and ionisation potential is of importance as is also the character of the gas in which the discharge occurs.

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Discharges may also be grouped according to certain external characteristics, as "burning," "striking" or "disruptive."

It would seem, however, that the above suggested subdivision is necessary as a basis for the correct description of an electric discharge. Much misunderstanding and patent litigation might be obviated if technical physicists would always explain to which of the above described distinguishing characteristics they wished to refer.

G. W. O. H.

An Analytical Method for Comparing the Rectifying Properties of Three-electrode Valves.*

By L. S. PALMER, M.Sc., Ph.D.

SYNOPSIS.

1. Introduction.
2. Nomenclature.
3. Theoretical Discussion.
4. Experimental Work.
5. Application to the Complete Characteristic.
6. Summary.

1. Introduction.—The following investigation was undertaken with the object of testing the validity of certain assumptions as to the form of the curved portion of the plate current—grid voltage characteristic of three-electrode valves. It was thought that an analysis based on these assumptions might yield some simple expression involving the known valve constants by which the rectifying properties could be predetermined. Somewhat similar investigations have been carried out by Van der Bijl,† Ballantine,‡ Carson,§ Breit,‖ and others using the generally accepted equations for the characteristic, but a comparison of the curves of the first and second derived equations with the curves obtained experimentally ¶ shows that the usual equations do not represent the changes of curvature of the characteristics with much accuracy.

The present work was suggested by Dr. B. Hodgson, who in 1916 carried out some measurements similar to those described on p. 472. During the course of the work Mr. E. V. Appleton ** obtained some first differential characteristics with his slope-meter and pointed out the use of such curves for indicating the amplifying and rectifying properties of valves.

* Received in final form June 24th, 1921.

† *Proceedings of the Institute of Radio Engineers*, 7, p. 603.

‡ *Proceedings of the Institute of Radio Engineers*, 7, p. 129.

§ *Proceedings of the Institute of Radio Engineers*, 7, p. 187.

‖ *Physical Review*, 16, pp. 387, 408.

¶ *Proceedings of the Institute of Radio Engineers*, 7, pp. 609, 610.

** *Proceedings of the Cambridge Philosophical Society*, 20, p. 239.

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2. Nomenclature.—The following nomenclature has been adopted throughout this paper :—

General Symbols.

V = Plate voltage.

v = Grid voltage.

v_f = Filament voltage.

I = Plate current.

i = Grid current.

i_f = Filament current.

θ = Angle of slope of straight portion of the (I, v) characteristic.

ϕ = Angle of slope of straight portion of the (I, V) characteristic.

α_m = Maximum value for $\frac{dI}{dv} = \tan\theta$.

β_m = Maximum value for $\frac{dI}{dV} = \tan\phi$.

$\lambda = \frac{\beta}{\alpha}$ = Voltage amplification factor.

$r_\alpha = \frac{1}{\alpha}$ = Filament-grid resistance.

$r_\beta = \frac{1}{\beta}$ = Filament-plate resistance.

Special Symbols.

v_x = Grid voltage for any point x on the (I, v) characteristic.

v_w = Grid volts for which rectification is a maximum for any given plate voltage, *i.e.*, the best working grid voltage for detection.

v_0 = Value in volts between the grid potential for which the plate current is zero, and the potential at which the (I, v) characteristic becomes a straight line (Fig. 1), *i.e.*, $(v_{I=0} - v_{dI/dv = \text{const}})$, or the range in grid volts over which rectification can occur.

I_R = The nett or effective rectified plate current produced by an alternating input voltage on the grid.

For simplicity in the following equations that characteristic is considered for which the dotted line D.M. (Fig. 1) coincides with the plate current axis. This avoids the necessity for the introduction of superfluous constants.

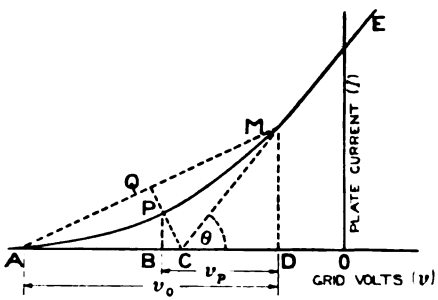

FIG. 1.

3. Theoretical Discussion.—Since rectification without a grid condenser depends upon the fact that the (I, v) characteristic of a three- electrode valve does not obey

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Ohm's law, it will be necessary to obtain the equation of the curved portion of the characteristic before any quantitative method for measuring rectification can be determined. The two following equations, depicted graphically in Figs. 2 and 3 respectively, were found to represent conveniently the lower curved portion of the (I, v) characteristics.

$$v^2 + I^2 + 2v_0v - \frac{2v_0}{\alpha_m}(1 + \alpha_m^2)^{\frac{1}{2}} I + v_0^2 = 0, \quad . \; . \; . \quad (1)$$

where α_m measures the characteristic slope at the point M (Fig. 2).

$$v^2 + 2\alpha_p Iv + \alpha_p^2 I^2 + 2v_0v - \frac{\alpha_p^4 + 1}{\alpha_p} v_0 I + v_0^2 = 0, \quad . \; . \quad (2)$$

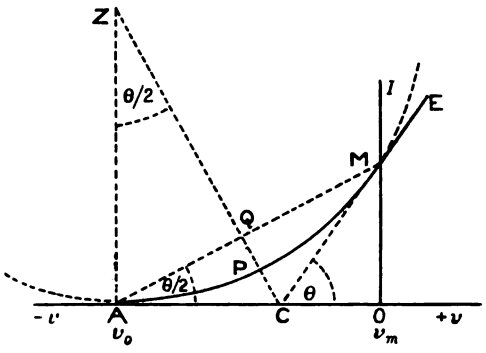

FIG. 2.

where α_p measures the slope of the characteristic at the point P (Fig. 3).

Equation (1) is that of the circle A P M of radius $\frac{v_0}{\alpha_m}(1 + \alpha_m^2)^{\frac{1}{2}}$ tangential to the straight line C M E at M and tangential to the grid voltage axis at A (Fig. 2). This form was found to coincide approximately with the characteristics of soft valves.

Equation (2) is that of the parabola *which has Q C as axis*, and which is also tangential to the straight line C M E at M and to the grid voltage axis at A (Fig. 3). Its minimum radius of curvature is at the point P and is half the length of the latus rectum, that is, it is given by $\frac{v_0}{2\alpha_p}(1 + \alpha_p^2)^{\frac{1}{2}}$. This curve approximates very closely to the experimental characteristics of hard valves.

Using these equations the "detection constant," $\frac{\delta v^2 \cdot f''(v)}{2}$ (obtained from the Maclaurin expansion of $I + \delta I = f(v + \delta v)$ *) can now be evaluated in terms of the known valve constants. This can be done most readily by writing the above expression in the form :—

$$I_R = \frac{\delta v^2}{2R}[1 + f'(v)^2]^{\frac{3}{2}} \; . \; . \quad (3)$$

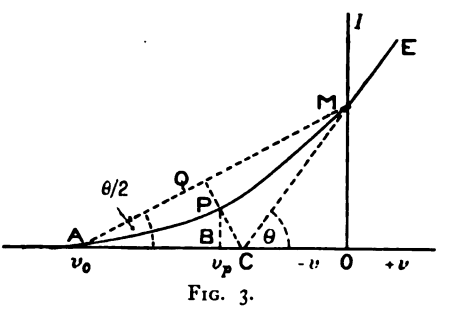

FIG. 3.

* *Proceedings of the Institute of Radio Engineers*, 7, p. 129.

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where R is the radius of curvature and $f'(v)$ the slope of the static characteristic at the particular working point, which, for maximum I_R, is that point where $f''(v)$ is a maximum.

For the circular form of the characteristic given by equation (1) the best working point (where $f''(v)$ is a maximum) is at M (Fig. 2), that is, $v_w = v_m$. For this point the values of R and $f'(v)$ are known (see p. 466) and substituting the values in equation (3) we get

$$I_R = \frac{\delta v^2(\alpha_m + \alpha_m{}^3)}{2v_0} \quad \ldots\ldots\ldots \quad (4)$$

With the parabolic form of the characteristic (equation (2)) the best working point lies somewhere between P and M (Fig. 3), for which R and $f'(v)$ are not easily determined. In practice the best working grid voltage (v_w) with hard valves was found to coincide very closely with v_p; that is, $v_w = v_p$ approximately (see Table II. and p. 473). For this point (v_p), R and $f'(v)$ are known (see p. 466) and when substituted in equation (3),

$$I_R = \frac{\delta v^2(\alpha_p + \alpha_p{}^3)}{v_0} \quad \ldots\ldots\ldots \quad (5)$$

If α_m is less than unity $\left(\text{as when measured in } \frac{\text{milliamps}}{\text{volts}}\right)$ both these expressions approximate to $\frac{\delta v^2 \cdot \alpha_m}{2v_0}$. Thus, if the assumptions involved in the foregoing analysis are sufficiently exact, and if the input grid voltage change (δv) be constant, then the expression $\frac{\alpha_m}{v_0}$ serves to measure *relatively* the value of I_R for any valve whose constants α_m and v_0 are known or can be determined. In other words, the expression $\frac{\alpha_m}{v_0}$ is a convenient measure of the relative rectifying efficiencies of three-electrode thermionic valves.

4. Experimental Work.—In order to test both equations (1) and (2) and the formula $\frac{\alpha_m}{v_0}$ the first and second differential characteristics were obtained experimentally (Figs. 4B and 5B) and compared with those plotted from the first and second differentials of equations (1) and (2) respectively (Figs. 4A and 5A). The curves of Fig. 4A are given by

$$\frac{dI}{dv} = -\frac{v + v_0}{I - \frac{(1 + \alpha_m{}^2)^{\frac{1}{2}}}{\alpha_m} \cdot v_0} \qquad \text{from equation (1)}$$

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and by $$\frac{dI}{dv} = -\frac{v + \alpha_p I + v_0}{\alpha_p\left(v + \alpha_p I - \frac{\alpha_p^4 + 1}{2\alpha_p^2} v_0\right)}$$ from equation (2).

The corresponding equations plotted in Fig. 5A are, from equation (1):—

$$\frac{d^2I}{dv^2} = -\frac{v_0^2(1 + \alpha_m^2)}{\alpha_m^2}\left[I - \frac{(1 + \alpha_m^2)^{\frac{1}{2}}}{\alpha_m} \cdot v_0\right]^{-3}$$

or $= -\frac{R^2}{(I - R)^3}$ where R is the radius of the circle, and from equation (2):—

$$\frac{d^2I}{dv^2} = -\frac{v_0^2(1 + \alpha_p^2)^4}{4\alpha_p^5}\left[v + \alpha_p I - \frac{(1 + \alpha_p^4)}{2\alpha_p^2} v_0\right]^{-3}$$

The similarity between these theoretical curves and the experimental curves of Figs. 4B and 5B justifies the original assumptions leading to equations (1) and (2) for the normal (I, v) characteristic.

In order to test experimentally the relative detecting efficiency of different valves, the plate potentials and filament voltage were kept constant at 40 volts and 3·5 volts respectively; that is, the detecting efficiencies under similar conditions were measured and not the maximum efficiency of any particular valve. Thus 3·5 volts on the filament of the N.P.L. No. 2 valve was too high, whilst the Moorhead tube would have been a much better detector than indicated if the filament volts had been raised to 5 or 6. All characteristic slopes were measured in $\frac{\text{amperes} \times 10^{-3}}{\text{volts}}$, this ratio being convenient both for graphical and numerical work.

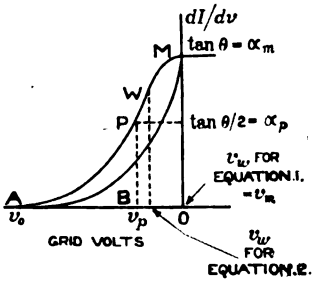

FIG. 4A.

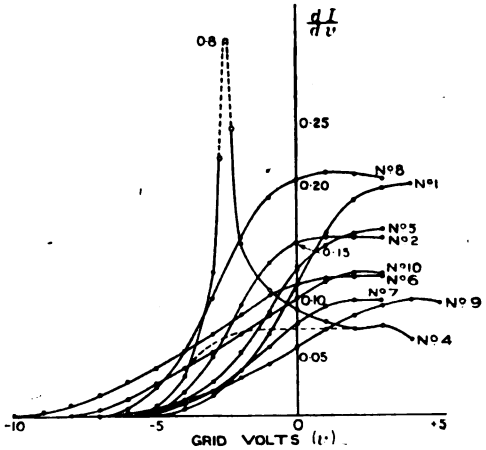

FIG. 4B.

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The actual ability of a given valve to receive signals was obtained by measuring the maximum distance (d) at which signals from a buzzer wave meter could be detected. For any two valves (1 and 2) suppose the maximum distances at which signals could be heard were d_1 and d_2 respectively. Then since signals could just be distinguished in the 'phones in each case:— $I_{R_1} = I_{R_2}$, whence, using equation (4),

$$\frac{(\alpha_{m_1} + \alpha_{m_1}^3)v_{0_2}}{(\alpha_{m_2} + \alpha_{m_2}^3)v_{0_1}} = \frac{\delta v_1^2}{\delta v_2^2} = \frac{d_1^3}{d_2^3}.*$$

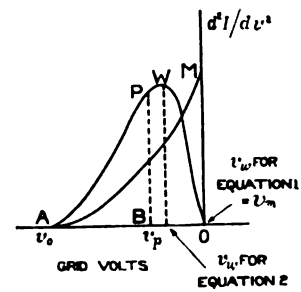

FIG. 5A.

Thus we can compare the relative detecting efficiencies calculated from either equations (4) or (5) with the relative efficiency determined by direct experiment. The results are given in Table I.

v_w was measured experimentally by noting the grid voltage for which d was a maximum for any given valve.

v_0 can also be measured approximately by determining the range in grid volts over which signals can be heard. It is, however, more accurate to read v_0 from the second differential characteristic, whilst α_m (and hence α_p) can be readily obtained from the height of the horizontal portion of the first differential characteristic, which, incidentally, is a measure of the amplifying properties of the valve. The data from these various methods is compared in Table II.

I_R is given directly by the maximum ordinate of the second differential curves.

The $\left(\frac{dI}{dv}, v\right)$ characteristic was obtained experimentally by measuring the value of λ, the voltage amplification factor, by a method previously described by the author † and by measuring β $\left(i.e.\ \frac{dI}{dV}\right)$ for varying grid voltages (v). The ratio $\frac{\beta}{\lambda}$ $\left(i.e.\ \frac{dI}{dv}\right)$ was plotted with v (Fig. 4B). A simpler more direct method is that described by Appleton.‡

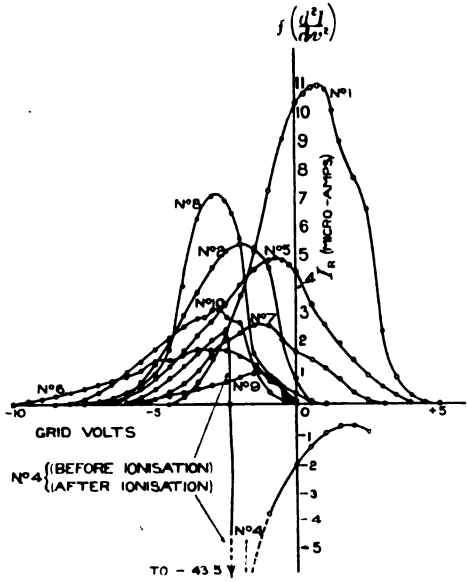

FIG. 5B.

* See Neumann, Maxwell, and also Butterworth, *Philosophical Magazine*, 31, p. 276.

† RADIO REVIEW, 1, p. 525.

‡ *Proceedings of the Cambridge Philosophical Society*, 20, p. 241.

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TABLE I.

No.	Valve. Description	Distance. d (max.)	Distance. d^3	$-v_0$ (volts)	$\frac{dI}{dv}$ a_m	$\frac{dI}{dv}$ a_p	Values of I_R. Experimental from $\left(\frac{d^2I}{dv^2}, v\right)$	$\frac{a_m}{2v_0}$	$\frac{a_m+a_m^3}{2v_0}$	$\frac{a_n}{v_0}$	Relative Values. Experimental. d^3	Experimental. I_R from $\left(\frac{d^2I}{dv^2}, v\right)$	Calculated. $\frac{a_m}{2v_0}$	Calculated. $\frac{a_m+a_m^3}{2v_0}$	Calculated. $\frac{a_p}{v_0}$	
							μamps.									
1	Mullard, F. (soft)	14·0	2,740	8·0	0·200	0·101	+ 11·1	0·0125	0·0130	0·0126	2·3	1·95	1·10	1·14	1·14	
2	Mullard, R. (hard)	10·6	1,190	7·0	0·155	0·077	+ 5·7	0·0113	0·0114	0·0110	1·00	1·00	1·00	1·00	1·00	
3	N.P.L. No. 2 (soft)	24·8					(Valve "Dued" with voltages used)									
4	R.2A. (soft)	8·0	512	7·0	0·080	0·040	+ 2·5	0·0057	0·0057	0·0057	0·43	0·44	0·50	0·50	0·50	*
		20·0	8,000	2·5	0·800	0·350	43·5	0·1600	0·525	0·1400	6·70	7·5	14·1	46·0	14·2	†
5	Seddig, R. J. W. (hard)	10·0	1,000	7·5	0·160	0·079	+ 5·1	0·0107	0·0109	0·0105	0·84	0·90	0·94	0·95	0·95	
6	Telefunken, D.R.P., F.V.N. 171 (medium)	7·5	422	10·5	0·120	0·060	+ 1·9	0·0059	0·0059	0·0056	0·35	0·33	0·52	0·51	0·51	
7	Siemens and Halske (medium)	8·2	551	7·5	0·100	0·049	2·8	0·0067	0·0067	0·0065	0·46	0·49	0·59	0·58	0·59	
8	Fotos, R. (French) (hard)	12·0	1,730	6·5	0·210	0·104	+ 7·4	0·0162	0·0168	0·0160	1·45	1·30	1·43	1·47	1·45	
9	Moorhead (American) (soft)	6·0	216	12·5	0·100	0·049	+ 1·1	0·0039	0·0040	0·0038	0·18	0·20	0·34	0·35	0·34	
10	Mullard, K. (hard)	8·6	636	8·5	0·121	0·061	+ 3·3	0·0071	0·0072	0·0071	0·53	0·58	0·63	0·63	0·64	

* Measurements before IONISATION occurred.
† Measurements after IONISATION occurred.

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The second derived characteristics $\left(\frac{d^2I}{dv^2}, v\right)$ were obtained by keeping a buzzer wavemeter close to the induction coil of the jigger circuit and noting the increase (or decrease) in the plate current as the grid volts were changed. The variation in plate current was greatest when the grid volts equalled v_w. The resulting curves are shown in Fig. 5B. Dr. Hodgson, by measuring the sound intensity in the 'phones, had obtained similar curves in 1916.

From the results of the experiments recorded in Table I. it can be seen that equations (4) and (5) give roughly the same values for I_R, but that these values agree with those obtained by direct experiment in order of magnitude only. This indicates that the two original assumptions as to the form of the (I, v) characteristic were only very approximate. The calculated values differ most from those observed in the case of soft valves in which ionisation must be occurring. The ionisation currents imposed upon the thermionic current tend to prevent the characteristic following the parabolic path which it apparently does in the case of hard valves. The variations in the gas pressure of soft valves also lead to different numerical values from day to day, whilst the hard valves remain fairly constant. The formula $\frac{\alpha_m}{v_0}$ does, however, give sufficiently accurate results to enable most valves to be classified according to their rectifying efficiencies.

The case of valves Nos. 7 and 10 illustrates the importance of the term

TABLE II.

Valve.		Values of v_m			Value of v_p	Values of v_w		
No.	Description.	Max. Limit of v_0 by sound.	From $\left(\frac{dI}{dv}, v\right)$	From $\left(\frac{d^2I}{dv^2}, v\right)$		Grid Volts for max. sound.	From $\left(\frac{dI}{dv}, v\right)$	From $\left(\frac{d^2I}{dv^2}, v\right)$
1	Mullard, F. (soft)	+3·5	+3·0	+3·5	+2·0	+1·0	+0·8	+0·3
2	Mullard, R. (hard)	+1·0	+1·0	+1·0	−2·4	−2·0	−2·0	−2·0
3	N.P.L. No. 2 (soft)	—	—	—	—	—	—	—
4	R.2A. (soft)	— +1·5	−2·2 (?) +1·0	−2·2 +0·5	−2·9 −2·0	— −2·1	−2·5 −2·0	−2·5 *) −2·0 †)
5	Seddig, R. J. W. (hard) . . .	+2·5	+2·5	+2·0	−1·2	−1·0	−1·2	−1·4
6	Telefunken, D.R.P., E.V.N. 171 (medium)	+1·6	+1·0	+1·0	−3·6	−3·3	−3·5	−3·5 (?)
7	Siemens and Halske (medium) . .	+2·0	+1·5	+1·0	−1·6	−1·2	−1·2	−1·0
8	Fotos, R. (French) (hard). . .	−0·5	0·0	0·0	−3·0	−2·8	−2·7	−3·0
9	Moorhead (American) (soft) . .	+4·9	−1·0	−1·0	−1·4	−1·1	−1·1	−1·7
10	Mullard, K. (hard)	+1·0	+0·5	+1·0	−2·8	−2·7	−2·7	−2·7

* Measurements before IONISATION occurred.
† Measurements after IONISATION occurred.

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α_m, for from consideration of v_0 (the term proportional to R in equation (3)) valve No. 7 should be a better rectifier than No. 10. The reverse was found to be the case both by experiment and by calculation. From the values of α_m only (the term proportional to $f'(v)$ in equation (3)) valve No. 6 should rectify better than No. 7. The calculated values from either formula show No. 7 to be the better, which is also in agreement with the experimental order of efficiency.

From Table II., the discrepancy between v_w found experimentally and v_w taken from the experimentally derived characteristics is quite small, whilst v_p differs from v_w considerably in the case of soft valves such as Nos. 1 and 4, but agrees much more closely in hard valves where the difference is practically negligible.

5. Application to the Complete Characteristic.—(1) *Symmetrical Characteristics.* — Assuming the ordinary characteristic of a valve to have similar bends at Y and Z (Fig. 6), and neglecting any effects due to grid current, the derived characteristics would take the forms indicated in the figure. In practice these curves are modified in three ways :—

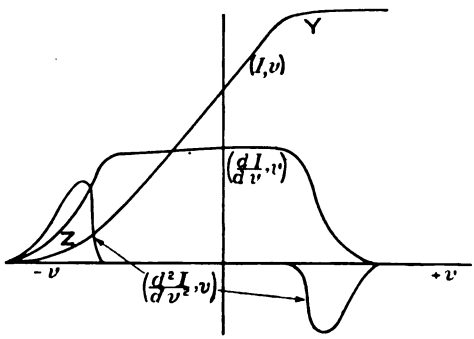

FIG. 6.

(*a*) The attainment of saturation, in the case of hard valves, takes place more suddenly than the growth of the current from zero. In other words the bend Y is usually of greater curvature than the bottom bend Z, *i.e.*, r_0 at Y is less than r_0 at Z.

(*b*) The presence of a grid current tends to decrease the rate of increase of the plate current for positive values of grid potential. This reduces the value of α_m at the upper bend Y.

(*c*) The presence of a gas in the valve tends to prevent saturation and may very considerably reduce α_m at Y whilst at the same time increasing r_0. This, of course, assumes ionisation is taking place.

(2) *The Hard Valve Characteristics.*—The effect (*b*), in the case of hard valves is, in general, less than the effect (*a*), *i.e.*, the reduction in the value of α_m is comparatively less than the reduction in r_0. Hence the combined effect is to make $\frac{\alpha_m}{r_0}$ for the upper bend Y greater than $\frac{\alpha_m}{r_0}$ for the bend Z. This is clearly seen in Appleton's curve and in the hard valve characteristics of Fig. 7, where the slope of the first derived curve for positive grid volts is steeper than that for negative grid volts. This means that the upper bend of a hard valve characteristic is a better rectifying region than

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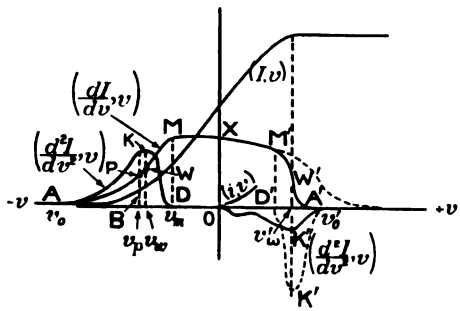

FIG. 7.

the lower bend. Ballantine * states the reverse to be the case, and was therefore using soft valves; a fact which is borne out by the "hump" on his first derived characteristics given on page 181 of the discussion on his paper.

In practice, however, the presence of a grid current damps the incoming oscillations and the actual result at Y is much less than that at Z. This difficulty was first realised by Dr. Hodgson who designed one amplifier in which the bend Y was brought to zero grid volts by reducing the filament temperature, a method now in common practice. Thus the experimental second differential curve, as indicated by sound intensity, takes the form indicated in Fig. 7; the lower dotted curve being the theoretical curve deduced from the first differential curve.

The amount of this reduction due to the flow of grid current can be approximately calculated by considering the filament-grid to be a high resistance (r_a) shunted across the condenser of the closed oscillatory circuit (Fig. 9). Suppose a current i_1 ($= I \sin \omega t$) be received in the aerial circuit which is coupled to the jigger circuit, the coefficient of mutual inductance of which is M. If at any instant the condenser charge be q; then ($\overline{V}_A - \overline{V}_B$) (*i.e.*, the potential difference across the condenser) is given by :—

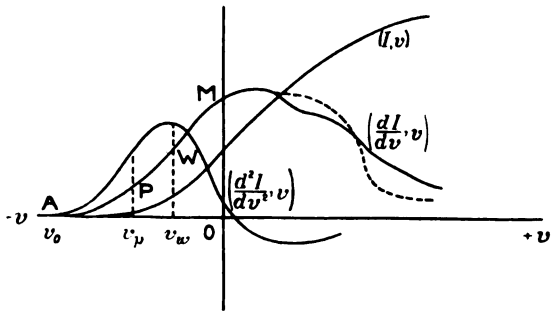

FIG. 8.

$$L\frac{dx}{dt} + Rx + M\frac{di_1}{dt} = r_a \cdot y \quad \ldots\ldots\ldots \quad (6)$$

and by

$$\frac{V}{C} \text{ or } -\frac{i_2}{C}\,dt = r_a y \quad \ldots\ldots\ldots \quad (7)$$

where i_2 is the current from the condenser and divides into x and y in the jigger and valve circuits respectively (Fig. 9). That is,

$$L\frac{dx}{dt} + Rx + MI\omega \cdot \cos \omega t = r_a y,$$

* *Proceedings of the Institute of Radio Engineers*, 7, p. 137.

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and from (7) putting $i_2 = x + y$

$$r_a \frac{dy}{dt} + \frac{x+y}{C} = 0 \quad \ldots\ldots\ldots \quad (8)$$

Substituting the value of y from (6) in equation (8)

$$L\frac{d^2x}{dt^2} + \left(R + \frac{L}{Cr_a}\right)\frac{dx}{dt} + \frac{1}{C}x = -M\frac{d^2i_1}{dt^2} - \frac{M}{Cr_a}\frac{di_1}{dt}.$$

Putting $\omega^2LC = 1$ for resonance, the particular integral x is given by

$$\frac{MI}{\left(R + \frac{L}{Cr_a}\right)}\left[\frac{1}{Cr_a}\sin\omega t - \omega\cos\omega t\right]$$

Substituting this value for x in equation (6), $(\bar{V}_A - \bar{V}_B)$ is equal to :—

$$r_a y = \frac{LMI}{\left(R + \frac{L}{Cr_a}\right)}\left[\frac{\omega}{Cr_a}\cos\omega t + \omega^2\sin\omega t\right] +$$

$$+ \frac{RMI}{\left(R + \frac{L}{Cr_a}\right)}\left[\frac{1}{Cr_a}\sin\omega t - \omega\cos\omega t\right] + MI\omega\cos\omega t$$

$$i.e., (\bar{V}_A - \bar{V}_B) = \frac{MI}{\left(R + \frac{L}{Cr_a}\right)}\left[\frac{2\omega L}{Cr_a}\cos\omega t + \left(\omega^2L + \frac{R}{Cr_a}\right)\sin\omega t\right]$$

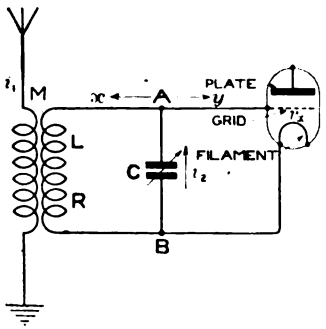

FIG. 9.

which reduces to $\left(\frac{MI}{RC}\right)\sin\omega t$ when r_a becomes infinite, or when no grid current is flowing. Hence the maximum value of the potential difference across the condenser when a grid current is flowing (using the fact that $(\omega^2LC = 1)$) is given by :—

$$\frac{MI}{\left(R + \frac{L}{Cr_a}\right)}\left[\left(\frac{R}{r_a} + 1\right)^2\frac{1}{C^2} + \frac{4L}{C^3r_a^2}\right]^{\frac{1}{2}} \quad . \quad (9)$$

reducing to MI/RC when $r_a = \infty$ . . (10)

It has been shown that rectification depends on the square of the grid voltage change (equation (3)), the maximum amplitude of which is given by (9) when a grid current is present in the valve or by (10) when no grid current

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flows. Hence, the reduction in rectification due to a grid current is given by $\left(\frac{\text{expression 9}}{\text{expression 10}}\right)^2$; this is by—

$$\frac{R^2C^2}{\left(R+\frac{L}{Cr_a}\right)^2}\left[\left(\frac{R}{r_a}+1\right)^2\frac{1}{C^2}+\frac{4L}{C^3r_a^2}\right] \text{ or } \frac{\left[(R+r_a)^2+4\frac{L}{C}\right]}{\left[r_a+\frac{L}{RC}\right]^2} \quad . \quad . \quad (11)$$

In general, r_a is large compared with R or with $\sqrt{\frac{L}{C}}$, hence the reduction factor is approximately equal to

$$\frac{1}{\left(1+\frac{L}{r_aRC}\right)^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

With $L = 2 \times 10^{-4}$ henries (2×10^5 e.m. units)
$C = 5 \times 10^{-10}$ farads (5×10^{-19} e.m. units)
$R = 10$ ohms (1×10^{10} e.m. units)
$r_a = 10^5$ ohms (1×10^{14} e.m. units)
} for a wavelength of 600 metres

both expressions (11) and (12) are equal to 0·51, that is, the actual rectification is only about half that expected from the slope of the first differential characteristic. If the grid current increases and reduces r_a to 10,000 ohms then the reduction factor drops in value to 0·04, in which case the valve almost ceases to detect on the upper characteristic bend. On the other hand if r_a increases to a million ohms the rectification is only reduced in the ratio of 1 to 0·92 and becomes unity when r_a is infinite. In other words there is no reduction in rectification when no grid current flows.

The expression (12) also indicates that as the capacity is increased with a corresponding reduction in the inductance, then the effect of the grid current is less appreciable. For example, if $C = 1 \times 10^{-18}$ e.m. units and $L = 1{\cdot}02 \times 10^5$ e.m. units (for a wavelength of 600 metres) the correction factor increases from 0·51 to 0·82. This effect was quite noticeable in practice.

From Fig. 7 the expected ratio of rectification at v_w' to that at v_w is given by—

$\frac{M'D'}{A'D'} \times \frac{AD}{MD}$ from the first derivative or $\frac{v_w'K'}{v_wK}$ from the second derivative.

These ratios are greater than unity, but in practice the actual value is given by $\frac{v_w'}{v_w} \cdot \frac{K''}{K}$ which is, as a rule, much less than 1, owing to the damping effect of the grid current discussed above.

When the filament was first heated the valve was slightly softer and gave the modification of the first derived characteristic indicated by the dotted portion of this curve (see also p. 477 and Fig. 8).

The bend at zero grid volts (Fig. 7) indicates a poor rectifying point

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which is hardly noticeable in the normal characteristic but is clearly seen in the fall XM′ in the $\left(\frac{dI}{dv}, v\right)$ characteristic, and by the portion OD′ in the $\left(\frac{d^2I}{dv^2}, v\right)$ curve.

(3) *The Soft Valve Characteristics.*—The effects (*a*) and (*b*) discussed above are but secondary effects when compared with (*c*), that due to the presence of a residual gas. Not only are soft valves less reliable in their action, but the foregoing theory does not give results in keeping with experiment, since the ionisation currents superimposed on the normal thermionic current cause the characteristics to vary considerably from any regular law. This was noted in valves Nos. 1 and 4 in particular. A typical set of characteristics from a soft valve are shown in Fig. 8. They all indicate that the upper bend is useless as a rectifying point owing to the small value of α_m and the very large value of v_0. In addition the $\left(\frac{dI}{dv}, v\right)$ curve often exhibits a "hump" for negative values of grid volts when ionisation occurs in the valve. This, according to Ballantine, is "apparently inexplicable," but is actually an indication of an abnormal increase in plate current when ionisation sets in.

The dotted curve was obtained after the filament had been heated for an hour and indicates a slight hardening of the valve with use. The same effect, but in the opposite direction, was noted in the case of the hard valve (Fig. 7). This change of slope depends on the varying amount of ionisation produced in the valve and upon the occlusion from the hot filament or absorption by the cold glass of the contained gas. The change is thus a test of the gas pressure similar in principle to the ordinary "back lash" test or to the principle underlying the ionisation gauge described by Dushman and Found.* In this way the change in slope of this portion of the $\left(\frac{dI}{dv}, v\right)$ characteristic is a sensitive measure of the change in the gas pressure in the tube.

6. Summary.—(1) The lower curved portion of the (I, v) characteristic of a three-electrode valve was assumed to approximate to (*a*) an arc of a circle, (*b*) a parabola.

(2) The first and second derived characteristics based upon these assumptions were compared with actual curves obtained experimentally from ten different valves. The parabolic form of the (I, v) characteristic yielded differential curves approximating fairly closely with the experimental curves of hard valves. The circular form of the (I, v) characteristic corresponded more closely with the soft valve characteristic, but the similarity was much less.

(3) The formula $\frac{\alpha_m + \alpha_m^3}{2v_0}$ deduced from assumption (*a*) above, and

* *Journal of the Franklin Institute*, 188, p. 819, December, 1919.

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the formula $\frac{\alpha_p + \alpha_p^3}{r_0}$ deduced from assumption (*b*) above, were found to give the same values for the relative rectifying efficiency. Also these two formulæ, together with the more approximate expression α_m/r_0 were sufficiently exact to enable the valves to be classified in the order of their efficiency as detectors.

(4) The absolute values given by the above formulæ when compared quantitatively with those obtained by direct experiment agreed approximately in the case of hard valves only.

(5) The formula $\frac{1}{\left(1 + \frac{L}{r_a RC}\right)^2}$ was deduced in order to evaluate the grid damping factor.

(6) The extension of the investigation to the complete characteristic is discussed in the last section. It was found that the variation in the slope of the $\left(\frac{dI}{dv}, v\right)$ characteristic for positive grid volts was a sensitive indication of the change in the gas pressure in the valve.

This work was carried out in the Physics Department of the University of Bristol. My best thanks are due to Dr. B. Hodgson whose preliminary work, leading to this investigation, was placed at my disposal; and also to Mr. H. G. Hughes of this University who assisted with the experimental work.

The expenses entailed in this research were defrayed by a grant from the University Colston Research Fund.

The French and German valves were lent by the Board of Industrial and Scientific Research.

Berlin—London Wireless Service.*

On January 26th a duplex wireless service was opened between London and Berlin for a period of three hours daily, from 4 p.m. till 7 p.m.

The Stonehaven Wireless Station (**GSW**), being the only medium-power station available is used for the transmitting station on the British side, while Königswusterhausen (**LP**) Wireless Station is used on the German side, the respective wavelengths being 4,600 and 5,250 metres.

The transmitter at Stonehaven consists of an Admiralty 25-kW arc, which is operated from London by means of the telegraph land line. The receiving station in England is situated in a special room in the G.P.O. West, together with the land line apparatus and Wheatstone transmitter for operating the wireless key on the Stonehaven arc transmitter.

The signals from Berlin are recorded on an ordinary Wheatstone receiver,

* Abstracted from *The Post Office Electrical Engineers' Journal* (see Abstract No. 2314 in this issue for references).

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which is introduced in the local circuit of a special form of sensitive "bow-contact" relay actuated directly by the wireless signals. Trials are now being made of reception on the Creed apparatus.

Difficulties were at first experienced on account of the slight variations of wavelength emitted by Berlin and Stonehaven but the constancy of the waves of the two transmitting stations has been improved.

Atmospherics on these higher wavelengths are more violent than those experienced on the shorter waves below 2,000 metres, but little interference is experienced on this account owing to the use of highly selective receiving devices. By these devices the high-power station at Moscow, which uses a spark transmitter on approximately the same wavelength, is effectively eliminated from the tape records.

The following example shows the traffic passed to and from London between 4 p.m. and 7 p.m. on February 25th, which is a fair example of the normal working.

	Messages.	Words.
Received from Berlin	120	2,142
Sent to Berlin	85	1,373
	205	3,515

The average speed of transmission and reception varies between twenty-five and fifty words per minute. On account of the short period of the daily service greater reliability and quicker disposal of live traffic is obtained at these speeds than would be the case if higher speeds were employed.

The service is now extended to cover the periods from 1 a.m. till 5 a.m., 6 a.m. till 8 a.m., and 2 p.m. till 7 p.m. in connection with the Reparations Conference.

Electric Oscillations along Straight Wires and Solenoids.*

By Professor J. S. TOWNSEND, F.R.S.

The author described a number of experiments made in conjunction with Mr. J. H. Morrell to determine the relations between the frequencies of the normal oscillations of such systems. He explained the difference between these non-harmonic modes of oscillations or overtones and the harmonics of a non-sinusoidal oscillation, two things which are sometimes confused. He described a method of accurately calibrating wavemeters which consisted in setting up a valve oscillator to generate waves say of 5 metres length, the length being accurately determined by means of stationary waves on a Lecher wire system loosely coupled with the oscillating system. Another oscillating valve set say of 500 metres wavelength with a telephone receiver coupled to its anode circuit is loosely coupled with the 5-metre wave set and adjusted until exact resonance is obtained with its hundredth harmonic, the coincidence between the harmonics and the 5-metre wave being indicated by clicks in the telephone receiver. The exact order of the harmonic can be found by counting the number of coincidences in an octave, that is, n is determined by counting the difference between n and $2n$. The connections are shown diagrammatically in Fig. 1.

* Abstract of paper read before the Wireless Section of the Institution of Electrical Engineers, June 8th, 1921.

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In the discussion which followed, Professor Howe drew attention to somewhat similar measurements on a solenoid recently described in the *Archiv für Elektrotechnik* (Vol. 9, p. 1) which were made to test the theoretical results obtained by Lenz. In reply to questions

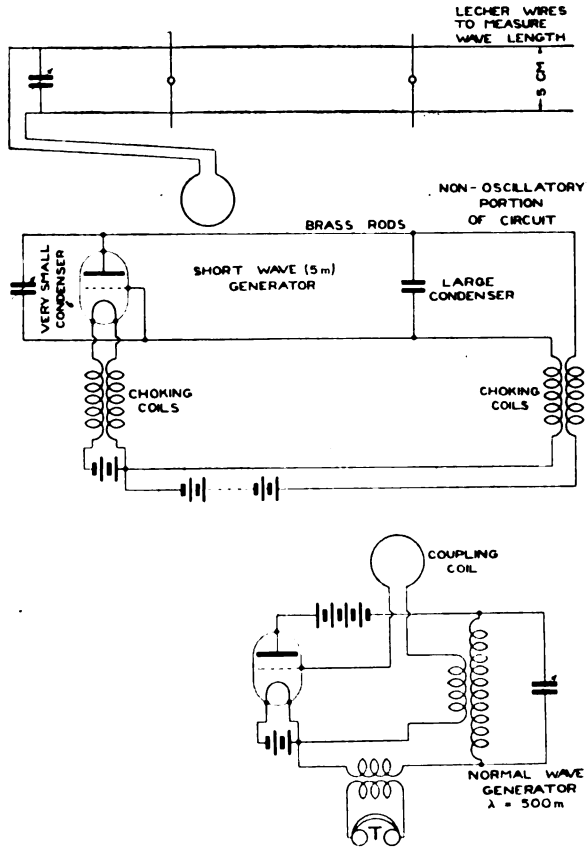

FIG. 1.

raised by several speakers Professor Townsend said that the distance between the Lecher wires could be varied within wide limits but that it was necessary to keep them away from anything likely to affect the waves.

The Piezo-Electric Properties of Rochelle Salt Crystals.

A demonstration of these properties was given by Mr. Philip R. Coursey, B.Sc., at the meeting of the Wireless Society of London held on June 27th, 1921. The apparatus that was shown was lent by Mr. E. Kilburn Scott, who had brought it from America, where many experiments on the subject have been carried out by Mr. McLean Nicolson, of the Western Electric Co.

Rochelle salts ($C_4H_4O_6NaK \cdot 4H_2O$) in common with many other crystalline substances possess the property of becoming electrified when subjected to torsion or pressure. This

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property may be shown in a striking manner with a crystal mounted between two alum plates, held together by springs, one of them being fitted with a needle which could take the place of an ordinary gramophone needle and sound box.

On applying the instrument to a gramophone record, sufficient voltage was generated to operate a loud-speaking telephone through a three-valve low frequency amplifier. The music was quite loudly reproduced and could be heard throughout the hall.

The apparatus is not a microphone operated by sound waves from the record, but transforms the vibrations of the needle directly into E.M.F.'s which can operate the amplifier.

The reverse action was also shown, a crystal mounted between two plates, and enclosed in a cylindrical parchment diaphragm, reproduced sounds spoken to a microphone in the primary circuit of a step-up transformer, across the secondary of which the crystal was connected.

In both cases the connections to the crystal were made between a tinfoil band round its centre, and its two ends which were connected together.

The Design of Resistance Coupled Amplifiers.

A paper by Lieut. N. H. Edes, R.E., with the above title was read at a meeting of the Wireless Society of London on June 27th, 1921. The paper pointed out that in most resistance-coupled amplifiers as now used there is no clear differentiation between the actions of amplification and rectification, and that it is usually assumed that the rectification is more or less distributed throughout the valves. When this is the case there must be considerable loss of efficiency, since owing to the reversal of phase with each valve, when grid current and damping are present each valve is in a position to amplify that halfwave of the oscillation which has been most damped by the preceding valve. To avoid this effect it is recommended that the amplifying valves should all have a negative potential on their grids, and that the rectifying valve should have a separate grid potentiometer.

From a consideration of the vector diagram representing the network of any one valve, it is shown that the value of the grid coupling condenser is immaterial as long as it is large compared with the grid-filament capacity of the valve, but that for efficient operation the resistance of the grid leak should be reduced for the shorter wavelengths.

Experimental Wireless Telephony.

A paper dealing with wireless telephony from the experimental point of view, and in particular treating of methods of modulation, was read before the Wireless Society of London by Mr. Philip R. Coursey, B.Sc., on May 2nd, 1921.

Descriptions were given of all the recognised methods of control and in addition a new arrangement was described under the name of "saturated valve" control. This arrangement makes use of the well-known fact that when the voltage applied between the plate and filament of a valve is steadily increased there comes a time when the anode current no longer rises with further increase of anode voltage. By suitably controlling the filament current this "saturation" of the valve can be brought about for almost any value of applied anode voltage. In the arrangement described such a saturated valve was employed to take the place of the ordinary choke coil in the "choke control" method, the saturated valve having the property of maintaining constant the flow of current through it and being practically independent of changes in the resistance of the circuit in which it is included. Demonstrations of the methods of modulation described were given.

A Universal Amplifier suitable for all Wavelengths.

A paper was given before the Wireless Society of London, on June 1st, 1921, by Mr. A. A. Campbell Swinton describing a Universal Amplifier suitable for all Wavelengths. The paper dealt with the practical design and construction of a six and a two-valve amplifier. The six-valve set had the first three valves operating at radio-frequency and transformer coupled, the fourth valve was the detector unit and the last two valves served as note magnifiers. In the two-valve set the first valve was operated at radio-frequency and the second was the detector valve.

The particular point of interest about the sets was the interchangeable radio-frequency transformers, several sets of these being employed for different wavelengths.

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Notes.

Personal.

The Institute of France has awarded the Triennial Osiris Prize of 100,000 francs to **General Ferrié**, Director of the French Wireless Service during the war. [3475]

Mr. E. P. Edwards, who has been assistant manager of the lighting department of the General Electric Company for a number of years past, has been made responsible for the radio activities of the company. Mr. Edwards will have immediate supervision of radio engineering, manufacturing and selling; negotiations with the Radio Corporation of America and other companies, and will in general direct the efforts of the company in the field of radio communication. [3601]

Mr. Douglas R. P. Coats has been appointed publicity manager of the Marconi Wireless Telegraph Co., Ltd., of Canada. [3606]

Colonel L. R. Krum, former superintendent of marine installations of the International Radiotelegraph Company, has joined the radio sales staff of the Westinghouse Electric and Manufacturing Company. [3607]

Mr. L. R. Robinson, formerly of the International Radiotelegraph Company, has severed his connection with the organisation. [3608]

Mr. R. A. Watson Watt has been appointed superintendent of the Radio Research Board wireless station at Aldershot. [3694]

Sir J. J. Thomson was recently elected honorary Professor of Natural Philosophy of the Royal Institution of Great Britain. [2677]

New Wireless Services, etc.

WIRELESS FOG SIGNALS are now transmitted continuously during thick or foggy weather from the following American light vessels:—Ambrose Channel light vessel, N.Y.; Fire Island light vessel, N.J.; Sea Girt lighthouse, N.J. These installations will also transmit the fog signals daily between 1400 and 1430 and between 2000 and 2030 on a wavelength of 1,000 metres to enable vessels to determine their positions from these stations. [3605]

MARKET REPORTS BY RADIOTELEPHONE.—The test of the Westinghouse radiophone made by the Bureau of Standards has been reported satisfactory and as a result the United States market reports will be sent broadcast through the Westinghouse radiotelephone station **KDKA** at East Pittsburg, each evening (except on Sundays) at about 9.30 p.m. E.S.T., on 300-metre wavelength. [E.S.T. = 5 hours earlier than G.M.T.]

It is possible for farmers within a distance of several hundred miles of East Pittsburg to learn of the agricultural market conditions and prices immediately after the closing of the market. [3596]

At the request of the Portuguese Government, arrangements are in progress for opening up wireless communication between Australia and the Portuguese East Indies. [3602]

The French Postal Telegraph Department has opened a public wireless service between France and Norway. [3031]

According to *The Times* a wireless receiving station has been erected at the Observatory, Perth, Western Australia, with which signals can be received over a distance of 12,500 miles. [3033]

According to a note in *Radio Nieuws* of May 1st, 1921, the Dutch military station at Soesterberg sends out a weather report by wireless telephony at 3.55 and 7.55 p.m. daily. [3632]

INTERCOLLEGIATE RADIO SERVICE.—The University of Texas at Austin and the Texas Agricultural and Mechanical College at College Station now exchange college news by wireless, and it is planned to extend the interchange of information to take in colleges in other States, including Harvard and Yale. [3655]

THE RADIO STATION AT BORKUM (latitude 53° 35 N., longitude 6° 40 E.) now transmits synoptic weather bulletins three times daily on a wavelength of 1,250 metres. The call letters are **KBN** and the times of transmission 0730, 1340 and 1915 G.M.T. [3662]

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TELEPHONY FROM NAUEN.—It has been announced that the Nauen Telefunken station has succeeded in establishing wireless telephonic communication with the S.S. *Bahia Blanca* over a range of 2,712 miles, and that the Königswusterhausen station similarly maintained communication with the vessel over a range of 2,185 miles. [3489]

RECEPTION OF BORDEAUX IN AUSTRALIA.—Signals from the new Bordeaux station (Lafayette) are regularly received for a period of at least twelve hours per day at the radio station at Koo-wee-rup (Victoria), owned by the Amalgamated Wireless (Australasia), Ltd. [3593]

Commercial and General.

COMPAGNIE GÉNÉRALE DE TÉLÉGRAPHIE SANS FIL.—The report recently issued stated that the company had obtained authority from the Argentine Government to establish and work a large radio station to ensure communication between Argentina and all other countries of the world. Similar negotiations have been made with other South American Governments —Ecuador, Colombia, Peru and Venezuela. The Compagnie d'Exploitation Radioélectrique which was formed in 1919 for working shipping installations is yielding favourable results and its scope of action is now beginning to extend beyond France. A contract has been concluded with the French Government for the construction and erection of radio stations for European and transocean communication, and a separate company—Compagnie Radio-France—was constituted in June, 1921, with a share capital of 60 million francs for the working of these stations which are now under erection in the neighbourhood of Paris. [3604]

ASSOCIATED MANUFACTURERS OF ELECTRICAL SUPPLIES, U.S.A.—A Radio Appliance Section has been added to this Association as a result of a convention of radio manufacturers held in New York City in March of this year. The section is under the chairmanship of **D. R. Murdoch**, of the W. J. Murdoch Company, Chelsea, Mass. The secretary is **G. J. Eltz**, of the Manhattan Electric Supply Company in New York City. Permanent committees will be formed to deal with the different phases of radio work. [3511]

WIRELESS TELEPHONE PROGRESS.—All the Instone "air liners" which are used regularly on the London-Paris service are now equipped with wireless telephony. Continuous practice is being carried out in direction finding and the general use of the radiotelephone gear. It is contemplated that a new ground installation will soon be required at Croydon to deal solely with radiotelephone messages from aircraft. [3495]

THE FEDERAL RADIO STATION AT SHANGHAI.—The new station at Shanghai, China, to be erected by the Federal Telegraph Company, will have the same kilowatt capacity as that of the Lafayette station at Bordeaux, but it will have six masts each 1,000 feet high as compared with the eight 826-foot masts at Bordeaux. [3487]

WIRELESS IN CHINA.—It has been stated that the United States intends to support the rights of the Federal Telegraph Company under its contract with the Chinese Government for the erection of wireless stations at Shanghai and elsewhere notwithstanding the protests of the British, Danish and Japanese Governments. [3603]

CALL SIGNALS.—The call signal **KSBV** has been assigned as a general call for all United States Shipping Board vessels and the call signal **KSPC** has been assigned as a general call for all vessels owned by the Standard Oil Company of New Jersey. [3597]

OPENING OF LEAFIELD (OXFORD) WIRELESS STATION.—The first British Station of the Imperial Wireless Chain was formally opened by the Postmaster-General on Thursday, August 18th, 1921. Congratulatory messages to British and foreign wireless stations were sent out. In a short speech the Postmaster-General stated that the station at Abu Zabal (Cairo) was being proceeded with rapidly, and that the delay in the completion of the stations had been due mainly to labour difficulties. A commission of experts was considering the design of the other stations recommended by the Imperial Wireless Telegraphy Committee. Pending the construction of these stations arrangements were being made for the further transmission to and from places beyond Egypt of telegrams forwarded by wireless between the Leafield and the Abu Zabal stations. [3695]

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WIRELESS INSTALLATIONS ON FRENCH VESSELS.—The French Government has published the following decision—" It is decided in France that ships of at least 500 tons shall be fitted with a receiving station. From 1,500 tons the ships shall have a complete receiving and transmitting station." [3693]

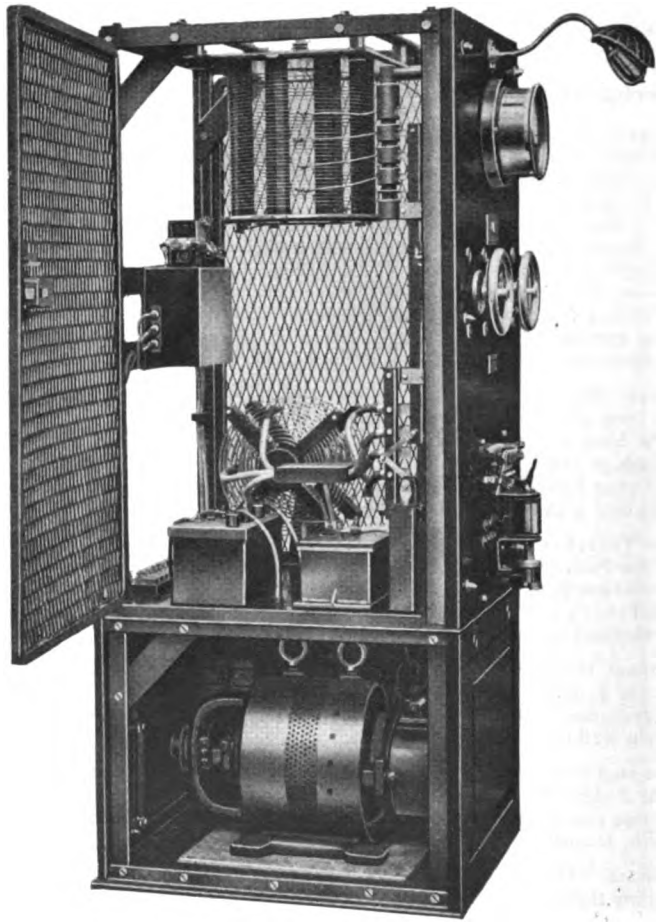

FIG. 1.

INTERNATIONAL WIRELESS CONFERENCE IN PARIS.—The International Radio Conference in Paris was formally opened on June 21st, a large number of representatives from Great Britain, France, United States, Italy and Japan being present. The purpose of the Conference is to harmonise the radio rules of the world and to consider a classification of the different wavelengths in accordance with their technical characteristics and to define the uses to be reserved for each, the distribution of wavelengths among the various services such as naval and aerial services, wireless telephony, etc., direction finding and meteorological services.

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The names of the delegates attending the Conference are :—

Great Britain.—Colonel Blandy (President), Colonel Gardiner, Mr. Shaughnessey, Mr. Lee, Captain Echevarri.

United States.—Major-General Squier (President), Admiral Magruder, Captain Evans, Professors Austin, Cohen, Dellinger and Kennelly, Major Mauborgne, Commandants Loftin and Craven, and Mr. Gothrie.

France.—General Ferrié (President), Inspector-General of Telegraphs Dennery, Professors Abraham and Mesny, Captain Lagorio, Commandant Noel, Captains Frank and Morcieau, and Engineer Perrin. In addition the following specialists are attached to the French delegation in the *rôle* of experts : Colonel Fracque, Commandants Chaulard, Jullien, Suberville and Le Breton, Captains Maistre and Bureau, Messrs. P. Brenot, Braillard and Viard.

Italy.—Professor Vallauri (President), Colonel Bardeloni, Commandants Biscia-Raineri and Gabetti and Signor Manzoni.

Japan.—General Shizuma, Captain Kiyokawa, Commandant Hattori and Captain Ishii.

[3484]

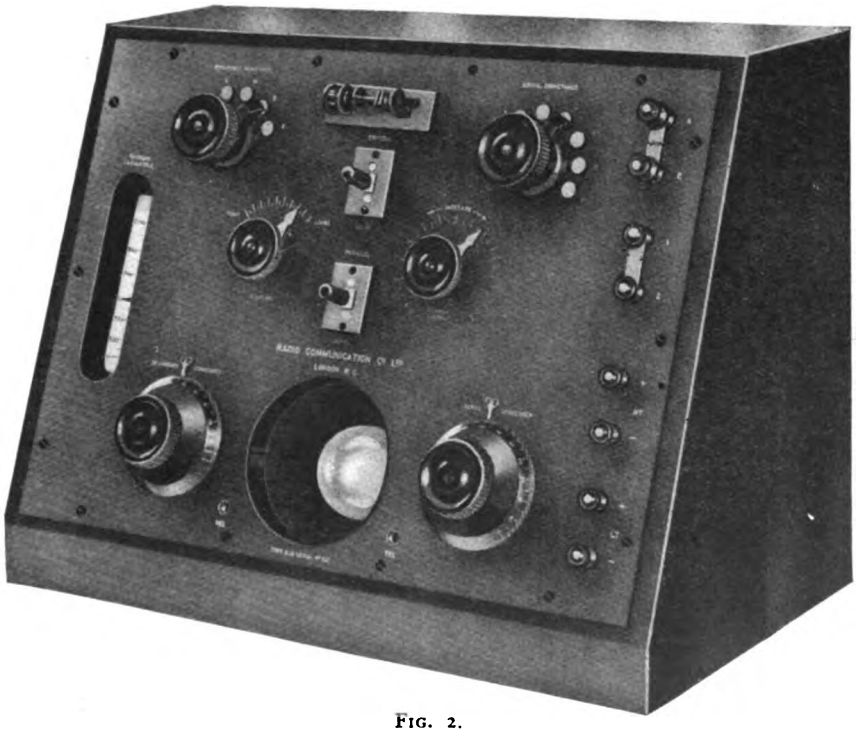

FIG. 2.

A DEMONSTRATION was recently given by the Radio Communication Co., Ltd., at their experimental wireless station at Slough, to members of the Wireless Society of London and their friends. The company's 1½-kW installation for ships (Fig. 1) was explained in detail and shown in operation, including the emergency set which works with a " Wilson " motor-driven commutator interrupter, and is included in the same panel, so that the main oscillating

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and aerial circuits are available for both sets. The standard single-valve receiver used with this set is illustrated in Fig. 2.

Some experiments in wireless telephonic transmission were carried out using a valve transmitter, and the 25-kW arc set also was shown in operation. This arc installation as fitted up at Slough is shown in Fig. 3, in which photograph may also be seen the control desk, and the automatically operated switches which control the various auxiliary circuits of the arc. [3697]

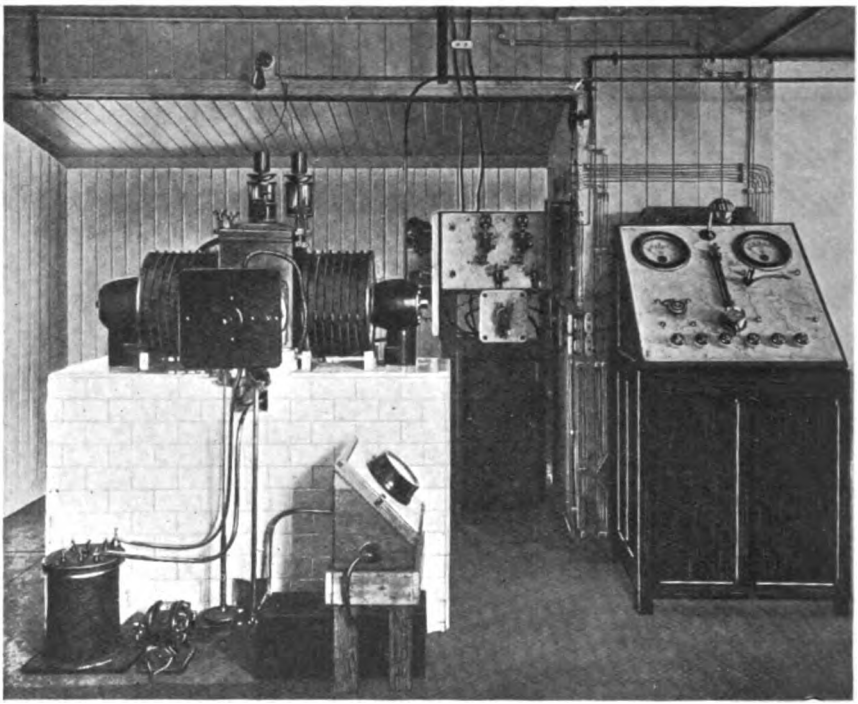

FIG. 3.

THE I.E.E. WIRELESS SECTIONAL COMMITTEE, 1921–22.—The following members have been nominated to serve on the Wireless Section Committee for 1921–22. Chairman: Dr. G. W. O. Howe. New nominations for committee: Major B. Binyon, O.B.E., Dr. W. H. Eccles, Messrs. G. H. Nash, C.B.E., and C. C. Paterson, O.B.E. The following will continue to serve as members of the committee: Sir Chas. Bright, F.R.S.E., Mr. R. C. Clinker, Professor C. L. Fortescue, Mr. A. Gray, Admiral of the Fleet Sir H. B. Jackson, G.C.B., Captain H. J. Round, M.C., Messrs. A. A. C. Swinton, F.R.S., and L. B. Turner. [2995]

THE STANDARDISATION COMMITTEE of the Institute of Radio Engineers is at work on a complete revision of the definitions of the technical terms which have come into use in the radio art within the past few years. It is expected that the committee's report will be ready for publication in book form in October or November of this year. [3136]

In order that Northern Manitoba may be brought into direct communication with other parts of the province, it is proposed that twelve wireless stations be installed immediately at a cost of £11,000. [3085]

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Review of Radio Literature.

1. Abstracts of Articles and Patents.

(U.) Miscellaneous Methods of Communication.

(2) EARTH CURRENT SIGNALLING.

2215. Earth Current Telegraphy. (*L'Industrie Électrique*, 29, p. 199, 1920. *Elektrotechnische Zeitschrift*, 41, p. 415, August 5th, 1920—Abstract.)

2216. **C. H. Roe.** Transmission of Electrical Energy. (*Wireless Age*, 8, p. 21, November, 1920.)

An alternating current conduction method of wireless communication is described.

2217. **Arendt.** Overhearing, Its Prevention and Earth Telegraphy; also Measurements on Earth Antennæ. (*Telegraphen- und Fernsprech-Technik*, 10, pp. 42—46, April, 1921.)

Report of a lengthy discussion on a paper with the above title. (See RADIO REVIEW Abstract No. 1526, February, 1921.)

2218. **E. F. Huth.** Thermionic Valves. (*British Patent* 149012, July 12th, 1920. Convention date November 15th, 1917. Patent not yet accepted.)

A device used for earth current signalling consists of a thermionic valve having tuned grid and plate circuits, and the earth plates connected across the plate circuit inductance. Reaction may be provided when required between the grid and plate circuits.

2219. **L. de Forest.** Buried Aerial Systems. (*British Patent* 160430, June 17th, 1920. Convention date March 13th, 1920. Patent not yet accepted.)

The buried aerial wires are connected to earth plates at the bottom of borings between 1,000 and 2,000 feet deep.

2220. **L. de Forest.** Electric Signalling through the Earth. (*British Patent* 145476, June 21st, 1920. Convention date June 16th, 1917. Patent accepted June 30th, 1921.)

2221. **A. Carletti.** Earth Telephone Interception during the War. (*L'Elettrotecnica*, 8, pp. 189—196, March 25th, 1921.)

A well-illustrated account of the methods and instruments employed by the Italian Armies for intercepting enemy communications and also for preventing the enemy from intercepting Italian communications.

(3) SUBMARINE SIGNALLING (including "Leader Cables").

2222. **F. Aigner.** On the Most Economical Transmission Frequency for Sound Signals in Air and Water for the Reception of Signals by Ear. (*Zeitschrift für Physik*, 1, pp. 161—173, 1920. *Journal de Physik et la Radium*, 1, Abstract Supplement p. 34, August, 1920—Abstract.)

For the most sensitive conditions the author concludes that a frequency in the neighbourhood of 1,000 per second is the best.

2223. **Submarine Signal Company.** Sound Detecting. (*French Patent* 499873, August 30th, 1918. Published February 25th, 1920. *British Patent* 133375 (**R. A. Fessenden**), August 1st, 1918. Patent accepted October 16th, 1919.)

The specification describes means for eliminating disturbances in sound receiving apparatus.

2224. **Submarine Signal Company.** Sound Signalling. (*French Patent* 500068, October 28th, 1918. Published March 2nd, 1920. *British Patent* 139530 (**R. A. Fessenden**), August 26th, 1918. Convention date August 16th, 1917. Patent accepted February 26th, 1920.)

The specification describes apparatus for the transmission and reception of acoustic waves, which is particularly suitable for directional signalling and for the location of submarines and submarine signalling stations.

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2225. **Submarine Signal Company.** Sound Detecting. (*French Patent* 503892, November 19th, 1917. Published June 19th, 1920.)

The apparatus described is for detecting low-frequency compressional impulses, particularly those emitted by submarines. The impulses are converted into electrical impulses which are rectified and observed with a direct current indicator. (See also **R. A. Fessenden,** *British Patent* 133081, of October 9th, 1917. Convention date May 21st, 1917. Patent accepted October 9th, 1919.)

2226. **A. Troller.** Submarine Signalling. (*La Nature*, 49(1), pp. 11—12, January 1st, 1921.)

2227. **R. L. Williams.** Microphone Transmitters. (*British Patent* 142096, April 19th, 1920. Convention date April 25th, 1918. Patent accepted October 7th, 1920.)

Describes a method of mounting a microphone on a thick diaphragm specially adapted for hydrophone use.

2228. **M. I. Pupin.** Sound Signalling. (*French Patent* 507608, December 20th, 1919. Published September 20th, 1920.

The specification describes apparatus for receiving high-frequency sound waves used for signalling and in which a crystal detector is employed.

For further particulars, see the *British Patent* 139496, RADIO REVIEW Abstract No. 1114, November, 1920.

2229. **P. Langevin.** Submarine Signalling. (*French Patent* 505703, September 17th, 1918. Published August 5th, 1920. *British Patent* 145691, June 30th, 1920. Convention date September 17th, 1918. Patent not yet accepted.)

The specification describes a transmitter or receiver for high-frequency vibrations used in directive subaqueous signalling. The device comprises a plate of quartz provided with metallic coatings to form a condenser. Pressure variations due to the received vibrations cause a potential difference between the two faces of the crystal and these can be detected electrically, for example by the heterodyne methods used in wireless signalling.

2230. **Signal Gesellschaft m.b.H.** Submarine Signals. (*French Patent* 506652, November 21st, 1914. Published August 27th, 1920.)

The specification describes receiving apparatus for acoustic submarine signals.

2231. **Signal Gesellschaft m.b.H.** Submarine Signals. (*French Patent* 506653, November 24th, 1914. Published August 27th, 1920.)

The specification describes receiving apparatus for acoustic submarine signals.

2232. **H. Lamb.** On the Vibrations of an Elastic Plate in Contact with Water. (*Proceedings of the Royal Society*, 98, pp. 205—216, November 3rd, 1920. *Science Abstracts*, 24A, p. 126, Abstract No. 285, February 28th, 1921—Abstract.)

2233. **A. Boutaric.** The Reception of Sounds under Water. (*Revue Scientifique*, 59, pp. 16—18, January 8th, 1921.)

2234. **J. J. Bennett.** The Leader Cable at Portsmouth. (*Engineering*, 111, pp. 187—190, February 18th, 1921. *Science Abstracts*, 24B, p. 208, Abstract No. 423, April 30th, 1921. *Electrical World*, 77, p. 951, April 23rd, 1921—Abstract.)

Photographic illustrations of the receiving apparatus are included with the description of the gear.

2235. **A. du Bois-Raymond, W. Hahnemann.** and **H. Hecht.** Development, Theory and Construction of the Submarine Sound Producer. (*Zeitschrift für Technische Physik*, 2, pp. 1—8, January, and 33—40, February, 1921.)

After a general discussion of the question, the oscillator constructed by the Signal Company of Kiel is described and illustrated. The damping and efficiency are discussed and it is shown how the mechanical oscillating system can be represented by an equivalent electric circuit. Two sizes are made with inputs of 250 and 800 watts respectively, the frequency is 1,000, the efficiency 50 per cent., and the weights 110 and 240 kgs. They are made to stand a pressure of 10 atmospheres.

2236. **W. A. Loth.** A New Method of Navigation for enabling a Ship to Enter or Leave a Harbour without Danger when the Ordinary Methods of Route Indications are not Available. (*Comptes Rendus*, 171, pp. 668—669, October 11th, 1920. *Scientific*

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American Monthly, 3, p. 377, April, 1921. *Radioélectricité*, 1, p. 83D, January, 1921—Abstract.)

2237. **A. Crossley.** Piloting Vessels by Electrically Energised Cables. (*Journal of the American Society of Naval Engineers*, 33, pp. 39—59, February, 1921. *Revue Générale de l'Électricité*, 9, pp. 645—655, May 7th, 1921—Abstract. *Engineer*, 131, pp. 567—568, May 27th, 1921—Abstract.)

After an historical *résumé* of the development of the method the author recounts some of the tests that have been made and gives a detailed description of the apparatus employed including a consideration of the cables and of their anchorages.

2238. **U. Bianchi.** A New Apparatus for Transmitting Photographs by Wire or Wireless. (*L'Elettricita*, pp. 33—36, March 1st, 1920. *Revue Générale de l'Électricité*, 7, pp. 202D—203D, June 26th, 1920—Abstract.)

An arrangement using valve amplifiers with selenium cells is described in detail.

2239. **Signal Gesellschaft.** Submarine Signalling. (*British Patents* 149324 and 149325, July 10th, 1920. Convention dates August 4th, 1919, and January 25th, 1917, respectively. Patents not yet accepted.)

2240. **Signal Gesellschaft.** Subaqueous Audible Signalling. (*British Patent* 149679, July 10th, 1920. Convention date October 1st, 1915. Patent not yet accepted.)

2241. **Signal Gesellschaft.** Sound Signalling Vibrators. (*British Patent* 144664, June 8th, 1920. Convention date October 23rd, 1915. Patent not yet accepted.)

A vibrator arrangement adapted to be unaffected by depth of immersion.

2242. **Signal Gesellschaft.** Receiving and Transmitting Sound. (*British Patent* 144673, June 9th, 1920. Convention date March 9th, 1916. Patent not yet accepted.)

A receiver for submarine signalling.

2243. **H. Lichte.** Electromagnetic Sound Producers. (*Zeitschrift für Technische Physik*, 2, pp. 12—17, January, 1921.)

A theoretical investigation based on Poincaré's equations for the telephone receiver. From the constants of the apparatus the author finds expressions for the damping and efficiency.

2244. **Signal Gesellschaft.** Sound Producers and Receivers. (*British Patent* 148759, July 10th, 1920. Convention date July 30th, 1919. Patent not yet accepted.)

Relates to the tuning of diaphragms for subaqueous signalling.

2245. **Signal Gesellschaft.** Submarine Signalling Apparatus. (*British Patents* 148974 [Convention date September 25th, 1917], 148975 [Convention date October 1st, 1917], 148972 [Convention date February 6th, 1915], 148973 [Convention date March 18th, 1916], 148976 [Convention date August 14th, 1918], 148977 [Convention date August 16th, 1918], 148978 [Convention date November 1st, 1918], 148979 [Convention date November 18th, 1918], 148980 [Convention date December 27th, 1918], 148982 [Convention date April 27th, 1917], 148985 [Convention date January 20th, 1920], 148986 [Convention date September 25th, 1917], 148987 [Convention date May 3rd, 1918], 148988 [Convention date May 19th, 1917], all filled July 10th, 1920. Patents not yet accepted.)

Describe various details of the transmitting and receiving apparatus for subaqueous audible signalling.

2246. **J. C. Manson.** Locating Submarine Cables. (*British Patent* 158923, August 29th, 1919. Patent accepted February 24th, 1921.)

Describes coils for navigational purposes using leader cables.

2247. **Signal Gesellschaft.** Indicating Fairways. (*British Patent* 159903, March 9th, 1921. Convention date March 12th, 1920. Patent not yet accepted.)

Deals with leader cables.

2248. **G. C. Evans** (Submarine Signal Company). Submarine Signalling Apparatus. (*British Patent* 151061, June 11th, 1919. Patent accepted September 13th, 1920.)

2249. **R. L. Williams** (Submarine Signal Company). Submarine Signalling. (*British Patent* 146125, June 23rd, 1920. Convention date June 24th, 1919. Patent accepted April 23rd, 1921.)

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A combination of submarine and wireless signalling to enable the distance of the sending station to be determined by the receiver.

2250. **R. A. Fessenden.** Subaqueous Audible Signals. (*British Patent* 146152, June 24th, 1920. Convention date November 29th, 1918. Patent accepted December 23rd, 1920.)

2251. **R. A. Fessenden.** Detecting Submerged Vessels. (*British Patent* 146155, June 24th, 1920. Convention date December 12th, 1918. Patent not yet accepted.)

2252. **H. C. Haynes** (Steward Davit and Equipment Corporation, U.S.A.). Determining the Direction of Sound or Wireless Waves. (*British Patent* 146188, June 25th, 1920. Convention date June 25th, 1919. Patent not yet accepted.)

2253. **H. C. Haynes** (Steward Davit and Equipment Corporation). Subaqueous Audible Signalling. (*British Patents* 146189 and 146190, June 25th, 1920. Convention date June 25th, 1919. Patents not yet accepted.)

2254. **M. Mason** (Steward Davit and Equipment Corporation). Determining the Direction of Waves. (*British Patent* 146192, June 25th, 1920. Convention date June 25th, 1919. Patent not yet accepted.)

2255. **G. W. Pierce** (Steward Davit and Equipment Corporation). Determining the Direction of Sound or Wireless Waves. (*British Patent* 146193, June 25th, 1920. Convention date June 25th, 1919. Patent not yet accepted.)

2256. **R. D. Fay** (Submarine Signal Company). Sound Transmitters and Receivers. (*British Patent* 160798, March 24th, 1921. Convention date March 26th, 1920. Patent not yet accepted.)

2257. **E. A. Graham** and **W. J. Rickets.** Detecting and Locating Sounds. (*British Patent* 162034, January 9th, 1920. Patent accepted April 11th, 1921.)

2258. **Q. C. A. Craufurd** and **Mrs. L. O. Doughty-Wylie.** Inductive Signalling. (*British Patent* 154978, September 1st, 1919. Patent accepted December 1st, 1920.)

2259. **J. A. Burgess** and **G. B. Hutchings.** Sound Filters. (*British Patent* 144799, March 17th, 1919. Patent accepted June 17th, 1920.)
A selective arrangement for subaqueous signalling, for eliminating interfering sounds.

2260. **Signal Gesellschaft.** Transmitters for Subaqueous Sound Signals. (*British Patent* 148409, July 10th, 1920. Convention date, March 13th, 1915. Patent not yet accepted.)
An addition to *British Patent* 14218/1913.

2261. **Signal Gesellschaft.** Subaqueous Sound Receivers. (*British Patent* 148410, July 10th, 1920. Convention date September 8th, 1915. Patent not yet accepted.)
An addition to *British Patent* 147936 (RADIO REVIEW Abstract No. 2289 in this issue).

2262. **Signal Gesellschaft.** Subaqueous Sound Signalling. (*British Patent* 148411, July 10th, 1920. Convention date April 4th, 1916. Patent not yet accepted.)
An addition to *British Patent* 147935 (RADIO REVIEW Abstract No. 2289 in this issue).

2263. **Signal Gesellschaft.** Sound Producers and Receivers. (*British Patents* 148412, July 10th, 1920 [Convention date June 5th, 1917], 148414, July 10th, 1920 [Convention date February 22nd, 1918], and 148415, July 10th, 1920 [Convention date July 11th, 1918]. Patents not yet accepted.)
Patents of addition to *British Patent* 147937 (RADIO REVIEW Abstract No. 2289 in this issue).

2264. **Signal Gesellschaft.** Submarine Sound Signalling. (*British Patent* 148413, July 10th, 1920. Convention date September 17th, 1917. Patent not yet accepted.)

2265. **Signal Gesellschaft.** Sound Transmitters. (*British Patent* 148416, July 10th, 1920. Convention date April 14th, 1919. Patent not yet accepted.)
An addition to *British Patent* 147945.* A series choking coil and a shunt condenser between the alternator and the sound producer are used to suppress undesired harmonics.

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* RADIO REVIEW Abstract No. 2289 in this issue.

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2266. **Signal Gesellschaft.** Receiving Subaqueous Signals. (*British Patent* 148417, July 10th, 1920. Convention date August 10th, 1917. Patent not yet accepted.)
An addition to *British Patent* 147947 (RADIO REVIEW Abstract No. 2289 in this issue).

2267. **Signal Gesellschaft.** Preventing "Clicks" in Telephones. (*British Patent* 148418, July 10th, 1920. Convention date March 30th, 1917. Patent not yet accepted.)
An addition to *British Patent* 147948.* Special switches are provided for changing over the receiving telephones to a number of circuits.

2268. **Signal Gesellschaft.** Ascertaining Direction of and Locating Sounds. (*British Patents* 148422 [Convention date May 29th, 1915], 148428 [Convention date November 5th, 1917] and 148429 [Convention date July 10th, 1915], July 10th, 1920. Patents not yet accepted.)

2269. **Signal Gesellschaft.** Submarine Signalling Apparatus. (*British Patents* 148423, 148424, 148425, 148426 and 148427, July 10th, 1920. Convention dates July 12th, 1915, November 29th, 1915, February 17th, 1916, March 15th, 1916, and March 3rd, 1917, respectively. Patents not yet accepted.)

2270. **H. Lichte.** Indicating Fairways. (*British Patent* 148430, July 10th, 1920. Convention date December 30th, 1918. Patent not yet accepted.)
Deals with leader cable arrangements.

2271. **R. A. Fessenden.** Submarine Signalling. (*British Patent* 148589, February 1st, 1919. Convention date February 1st, 1918. Patent accepted August 3rd, 1920.)
Relates to the screening of the apparatus from local noises.

2272. **A. Anderson.** Locating Sounds. (*British Patent* 148678, June 23rd, 1919. Patent accepted August 5th, 1920.)

2273. **Submarine Signal Company (U.S.A.).** Submarine Sound Generators. (*British Patent* 148703, September 25th, 1919. Patent accepted August 5th, 1920.)

2274. **Signal Gesellschaft.** Microphones. (*British Patent* 152616, October 16th, 1920. Convention date October 16th, 1919. Patent not yet accepted.)
Relates to a special construction of microphone to permit of uniform resonant qualities in different instruments made to the same general design.

2275. **R. A. Fessenden.** Acoustic Signals. (*British Patent* 146350, July 2nd, 1920. Convention date March 23rd, 1918. Patent not yet accepted.)

2276. **M. I. Pupin.** Sound Signalling. (*French Patent* 507609, December 20th, 1919. Published September 20th, 1920.)
The specification describes sound-generating apparatus in which electrical means are employed. See also *British Patent* 139497 (RADIO REVIEW Abstract No. 1174, November, 1920).

2277. **M. I. Pupin.** Sound Signalling. (*French Patent* 507610, December 20th, 1919. Published September 20th, 1920.)
The specification describes receiving apparatus for ultra-audible high-frequency vibrations. See also *British Patent* 139498 (RADIO REVIEW Abstract No. 1320, December, 1920).

2278. **R. A. Fessenden.** Sound Signals. (*British Patent* 146563, March 12th, 1919. Patent accepted June 12th, 1920.)

2279. **Signal Gesellschaft.** Sound Producers and Receivers. (*British Patent* 150265, August 16th, 1920. Convention date August 18th, 1919. Patent not yet accepted.)

2280. **J. Gardner.** Detecting Subaqueous Sounds. (*British Patent* 150379, May 2nd, 1919. Patent accepted September 9th, 1920.)

2281. **Siemens and Halske Akt. Gesellschaft.** Indicating Fairways. (*British Patents* 146959 [Convention date December 17th, 1918. Patent not yet accepted], 146960 [Convention date January 26th, 1916. Patent accepted March 17th, 1921], 146961 [Convention date December 16th, 1918. Patent accepted June 2nd, 1921], and 146962 [Convention date December 9th, 1918. Patent accepted February 24th, 1921], July 6th, 1920.)
A leader cable system.

* RADIO REVIEW Abstract No. 2289 in this issue.

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2282. **Signal Gesellschaft.** Sound Transmitting and Receiving Apparatus. (*British Patent* 155569, October 29th, 1920. Convention date December 15th, 1919. Patent not yet accepted.)

An addition to *British Patent* 148972.*

2283. **A. U. Samwark.** Locating Subaqueous Sounds. (*British Patent* 156230, January 4th, 1921. Convention date December 1st, 1919. Patent not yet accepted.)

The distance of a station which emits simultaneous wireless and submarine sound signals is determined by observing the time between the arrival of the two signals. A thermionic valve is used both for detecting the wireless signals, and for amplifying the sounds.

2284. **J. A. Burgess** and **G. B. Hutchings.** Detecting Sounds. (*British Patent* 151662, March 17th, 1919. Patent accepted September 17th, 1920.)

2285. **Signal Gesellschaft.** Subaqueous Signalling. (*British Patents* 157229, 157230, 157231, 157232, January 8th, 1921. Convention dates, December 10th, 1914, October 2nd, 1915, December 31st, 1917, and December 20th, 1919, respectively. Patents not yet accepted.)

2286. **R. A. Fessenden.** Detecting and Transmitting Sounds. (*British Patent* 145812, December 31st, 1918. Patent accepted June 30th, 1920.)

2287. **Q. C. A. Craufurd** and **Mrs. L. O. Doughty-Wylie.** Detecting Submarines, etc. (*British Patent* 154347, September 1st, 1919. Patent accepted December 1st, 1920.)

The presence of a distant submarine or other vessel on which electrical machinery is running is detected by a circuit comprising a capacity connected to earth and coupled to tuned alternator and detector circuits. Energy picked up from the distant vessel by the capacity causes alterations in the character or tone of the sound heard in the telephones.

2288. **T. F. Wall.** Subaqueous Sound Signalling. (*British Patent* 154009, September 12th, 1919. Patent accepted November 25th, 1920.)

2289. **Signal Gesellschaft.** Subaqueous Signals. (*British Patents*, 147934 [Convention date December 16th, 1914], 147935 [Convention date May 8th, 1915], 147936 [Convention date June 14th, 1915], 147937 [Convention date February 29th, 1916], 147938 [Convention date November 1st, 1916], 147939 [Convention date March 10th, 1917], 147940 [Convention date August 6th, 1917], 147941 [Convention date November 27th, 1917], 147942 [Convention date February 25th, 1918], 147943 [Convention date May 4th, 1918], 147944 [Convention date May 30th, 1918], 147945 [Convention date August 12th, 1918], 147946 [Convention date August 12th, 1918], 147947 [Convention date October 26th, 1914], 147948 [Convention date March 20th, 1917], all of July 9th, 1920. Patents not yet accepted.)

2290. **W. A. Loth.** On the Electromagnetic Piloting of Ships. (*Revue Générale de l'Électricité*, 9, pp. 899—903, June 18th, 1921.)

Correspondence relative to an article by A. Crossley† and drawing attention to earlier experiments on this subject.

2291. **P. H. Boucheron.** The Invisible Radio Pilot. (*Radio News*, 2, p. 272, November, 1920.)

An illustrated description of a leader cable equipment.

(4) AND (5) ACOUSTIC SIGNALLING AND "ELECTROSTATIC" WIRELESS SIGNALLING.

2292. **L. Biancoli.** Sound Locating. (*French Patent* 500641, June 11th, 1919. Published March 18th, 1920.)

The invention consists of an acoustic apparatus to locate the position in space of an aeroplane or other flying machine. The sound waves emanating from the machine are received in two resonators which cause, through relays, the closing of a local circuit in which electromagnetic means act on an indicator which shows which resonator is the more strongly affected.

* RADIO REVIEW Abstract No. 2245.

† See RADIO REVIEW Abstract No. 2237.

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2293. **R. A. Fessenden.** Sound Signa ling. (*British Patent* 151585, July 21st, 1920. Convention date July 19th, 1919. Patent accepted May 19th, 1921.)
Sound signalling apparatus for communication with aircraft or for subaqueous communication.

2294. **E. C. Hanson.** Wireless Telephone Apparatus. (*French Patent* 505499, October 28th, 1919. Published July 30th, 1920. *British Patent* 135504, November 10th, 1919. Convention date September 7th, 1915. Patent accepted April 11th, 1921.)
An arrangement for "electrostatic" wireless telephony not using a high-frequency carrier wave.

2295. **E. C. Hanson.** Wireless Telegraphic Apparatus. (*British Patents* 154530 and 154531, November 23rd, 1920. Convention dates August 27th, 1917, and June 4th, 1918, respectively. Patents not yet accepted.)
The apparatus uses audio-frequency currents only. Reception is effected by means of a thermionic valve.

2296. **E. C. Hanson.** Wireless Telephony. (*British Patent* 154537, November 23rd, 1920. Convention date June 18th, 1917. Patent not yet accepted.)
Valve amplifiers are used both for transmission and reception of the audio-frequency impulses.

(V.) Traffic Particulars of Radio Stations.

2297. Comparative Radiotelegraphic Statistics for 1919. (*Journal Télégraphique*, 45, pp. 26—35, February 25th, 1921.)
Tabular data with regard to the number of stations, the type of apparatus, number of operators, etc., in the various countries of the world.

2298. The Belgian Meteorological Bulletin. (*La T.S.F. Moderne*, 1, pp. 109—110, July, 1920.)
Details are given of the bulletins transmitted daily at 0725, 1315, and 1815 G.M.T. from the Royal Observatory, Belgium.

2299. **J. de Mare.** The Reception of Annapolis, NSS. (*La T.S.F. Moderne*, 1, pp. 110—112, July, 1920.)
Details are given of the time signals transmitted at 0255 and 1655 G.M.T. from this station.

2300. **P. Schereschewsky.** The International Meteorological Radio Telegrams. (*La Nature*, 49(1), pp. 268—271, April 23rd, 1921; pp. 275—279, April 30th, 1921.)
Refers to the international arrangements made for the distribution of meteorological information by wireless transmission from high-power stations in Europe and the co-ordination of results aimed at by the recent International Conference on Weather Telegraphy.* Details are given of the transmissions from Nauen, Königswusterhausen, Vienna, Copenhagen, Madrid, Great Britain, Holland, Italy, Norway, Poland, Sweden, Czecho Slovakia and Russia, and a chart is given with the reference Nos. of the meteorological observatories from which reports are collected.

2301. The Meteorological Radio Telegrams of the United Kingdom. (*Radioélectricité*, 1, pp. 473—474, February; pp. 564—565, April, 1921. *Wireless World*, 9, pp. 25—29, April 2nd, 1921.)

2302. Wireless Navigation Warnings. (*Radioélectricité*, 1, pp. 594—597, May, 1921.)
A table is given of the most important stations of the world which transmit navigation warnings to ships. The call letters, wavelengths and times of signalling are given.

2303. United States Weather Bureau Radio Forecasts. (*Radio Service Bulletin*, No. 48, pp. 14—18, April 1st, 1921.)
Gives particulars of the meteorological messages transmitted by the U.S. Naval radio stations.

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* See RADIO REVIEW, Note No. **1846**, p. 42, January, 1921.

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2304. **J. W. J. van Haersolte.** Radio Weather Reports. (*Radio Nieuws*, 4, pp. 131—132, May 1st, 1921.)
Particulars are given of the transmission from Vossegat.

2305. A High Speed Radio Service in Western Prussia. (*Annales des Postes, Télégraphes et Téléphones*, 10, p. 183, March, 1921. *Journal Télégraphique*, 45, p. 119, June 25th, 1921—Abstract.)
A short reference to modifications in the radio service between Berlin and Königsberg to permit of duplex working.

2306. **P. Corret.** Transmission Programmes. (*La T.S.F. Moderne*, 2, pp. 23—28, January, 1921.)
A twenty-four hour time table of transmissions from high-power stations.

2307. Regular Transmissions of Wireless Stations. (*Wireless World*, 9, pp. 85—89, April 30th, also Supplement, August 6th, 1921.)
A list of stations giving regular transmission. Times of working, call signs, wavelengths, etc., are given.

2308. Wireless Telephony to Holland. (*Electrical Review*, 88, p. 520, April 22nd, 1921. *Journal Télégraphique*, 45, p. 119, June 25th, 1921—Abstract.)
Refers to recent tests by the Nederlandsche Seintoestellen Fabriek in the distribution of Stock Exchange reports by wireless telephony to a large number of banks throughout Holland. A licence has also been granted to the Marconi Company by the British and Dutch Governments to experiment with wireless telephonic transmission between the two countries.

2309. Wireless Telephony in South Africa. (*Electrical Review*, 88, p. 620, May 13th, 1921.)
The Government of South Africa is said to be experimenting with wireless telephony with a view to linking the chief centres. Communication has successfully been established between Johannesburg and Bloemfontein.

2310. Long Distance Telephony. (*Electrical Review*, 88, p. 485, April 15th, 1921.)
Reference is made to a long distance telephonic communication partly by wire and partly by wireless between Havana and Catalina Island, the total distance being 5,056 miles.

2311. Wireless Transmission of Music. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, pp. 159—160, February, 1921.)
Refers to experiments in radio transmission of concerts from Königswusterhausen.

2312. Morse Alphabet for Radiotelegraphy. (*Telegraph and Telephone Age*, 39, p. 9, January 1st, 1921.)
A discussion of the relative merits of Continental and American Morse codes for radio working, with a recommendation that American Morse be used for railway wireless and similar traffic not addressed to other countries.

2313. Tuckerton to France Radio Service. (*Wireless Age*, 8, p. 9, March, 1921.)
A new link has been added between America and France by the recent opening of a regular radio service between Tuckerton, N.J., and Lyons, France. The Tuckerton station uses a 200 kW Alexanderson alternator, and the American receiving station is at Belmar, N.J. The receiving station on the French side is located at Ville Juif, near Paris.

2314. The Berlin-London Wireless Service. (*Post Office Electrical Engineers' Journal*, 14, pp. 33—34, April, 1921. *Elektrotechnische Zeitschrift*, 42, p. 232, March 10th, 1921—Abstract. (See pp. 478—479 in this issue.) *Annales des Postes, Télégraphes et Téléphones*, 10, p. 369, June, 1921.)

2315. United States—Indo-China Wireless. (*Electrical Review*, 88, p. 586, May 6th, 1921.)
Refers to the inauguration of a commercial radio service on May 1st between United States and Indo-China *via* Hawaii and Philippines.

(W.) Radio Conventions, Legislation, etc.

2316. Radio America shown to Foreign Experts. (*Wireless Age*, 8, pp. 10—16, December, 1920.)

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An account of the visits of the delegates to the International Communication Conference to various places of radio interest in America.

2317. The Radio Congress. (*Scientific American*, 25, p. 3, July 2nd, 1921.)
A short note with regard to the American delegates to the Radio Congress in Paris on June 21st, 1921.

2318. Removal of Wireless Restrictions. (*Sea, Land and Air*, 3, pp. 258—266, July, 1920.)
Particulars are given of revised radio legislation in Australia.

2319. Radio Legislation in France. (*Journal Télégraphique*, 45, pp. 74—77, April 25th, 1921.)
The text is given of the regulations of February, 1917, relating to private radio installations in France, and of a decree of June 2nd, 1920, modifying the earlier regulations.

2320. Japanese Radio Legislation. (*Radioélectricité*, 1, pp. 466—468, February; pp. 515—517, March, 1921.)

2321. Belgian Radio Legislation for the Safety of Ships. (*Radioélectricité*, 1, pp. 465—466, February, 1921.)

2322. Radio Legislation in Greece. (*Radioélectricité*, 1, pp. 559—562, April, 1921.)

2323. Radio Legislation in Iceland. (*Radioélectricité*, 1, pp. 604—605, May, and pp. 642—643, June, 1921. Abstracted from *Journal Télégraphique*.)

2324. Imperial Communication. (*Electrical Industries*, 21, pp. 879—881, July 13th, 1921.)
Some notes with regard to the difficulties of arranging satisfactorily the imperial wireless communications.

(X.) Biographies, Obituary Notices, etc.

2325. **J. Blondin.** (*Revue Générale de l'Électricité*, 9, pp. 347—348, March 12th, 1921.)
Biographical notice. (See RADIO REVIEW, 2, p. 262, May, 1921.)

2326. Who's Who in Radio—**Sir Oliver Lodge.** (*Radio News*, 2, p. 695, April, 1921.)
Biographical notes and portrait.

2327. Who's Who in Radio—**Dr. J. A. Fleming.** (*Radio News*, 2, p. 615, March, 1921.)
Biographical note with portrait.

2328. **G. W. Pickard.** (*Radio News*, 2, p. 784, May, 1921.)
A biographical sketch with portrait.

2329. **E. Branley.** (*Radio News*, 2, p. 867, June, 1921.)
Biographical notes and portrait.

2330. **Dr. Lee de Forest.** (*Radio News*, 2, p. 530, February, 1921.)
Biographical notes with portrait.

2331. **General George O. Squier, K.C.M.G., Ph.D.** (*Radio News*, 3, p. 23, July, 1921.)
Biographical sketch with portrait.

2332. **A. Schuster.** John William Strutt, Baron Rayleigh, 1842—1919. (*Proceedings of the Royal Society*, 98A, pp. 1—50, March 24th, 1921.)
A lengthy obituary notice including many references to his work in various branches of science.

2333. **Dr. Edward Bennett Rosa.** (*Journal of the American Institute of Electrical Engineers*, 40, p. 537, June, 1921. *Electrical World*, 77, p. 1144, May 21st, 1921.)
Obituary notices and biographical sketches with portrait.

(Z.) Miscellaneous Uses of Wireless, and H.F. Currents, Nomenclature, etc.

2334. A New Radio Instructor. (*Radio News*, 2, p. 686, April, 1921.)
An illustration of a special instructional panel designed by the Telefunken Company.

2335. Fused Silica Valves for Wireless Work. (*Electrician*, 86, p. 255, February 25th, 1921.)
A short note with regard to the recent developments of high power valves constructed in

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fused silica and designed by H.M. Signal School, Portsmouth. The manufacture of these valves is now in the hands of the **Mullard Radio Valve Co., Ltd.**

2336. **D. W. Horner.** Determination of Longitude. (*Nautical Magazine*, 105, pp. 334—340, April, 1921.

A lengthy abstract of a paper, Professor R. A. Sampson. (See RADIO REVIEW Abstract No. 2348 in this issue.)

2337. **R. L. Atwell.** The application of Wired Wireless, Radio, and Wireless Telephone to Railway Service Communication Systems. (*Telegraph and Telephone Age*, 39, pp. 55—56, February 1st, 1921.)

The importance of radio methods of communication, particularly as regards reliability, is emphasised for railway developments and extensions.

2338. **H. T. Wade.** A Wireless Storm Detector for the Central Lighting Station. (*Monthly Weather Review*, 48, p. 162, March, 1920.)

2339. **P. H. Boucheron.** Transmitting Photographs by Radio. (*Science and Invention* 8, pp. 883, and 932—934, December, 1920.)

An illustrated article giving details of the proposed method adapted to ordinary radio apparatus.

2340. **M. Moye.** The Practical Utilisation of Meteorological Radio Bulletins. (*La T.S.F. Moderne*, 1, pp. 180—184, September, 1920.)

2341. **C. F. Dodwell.** Adelaide Longitude by Wireless. (*Monthly Notices of the Royal Astronomical Society*, 81, p. 101, November, 1920. *Science Abstracts*, 24A, p. 156, Abstract No. 345, March 31st, 1921.)

Rhythmic signals from Lyons were received at Adelaide from June 23rd to July 5th, 1920. Comparing the recorded times with those at Greenwich, and allowing 0·04 seconds for time of transmission, the Adelaide longitude comes out 9 hours 14 minutes 19·95 seconds to compare with adopted value 9 hours 14 minutes 20·07 seconds.

Indirect determinations by means of series of Annapolis signals in July and August gave 9 hours 14 minutes 19·79 seconds and 9 hours 14 minutes 19·78 seconds respectively, but these have not the same weight as the Lyons signals, as the Annapolis signals received at Greenwich are those sent at 17 hours G.C.T., while those received at Adelaide are sent at 3 hours G.C.T.

2342. Vaudeville by Radio Telephony. (*Telegraph and Telephone Age*, 39, p. 179, April 16th, 1921.)

A short note with reference to the transmission of a concert by wireless telephony by **R. F. Gowen**, chief engineer of the de Forest Radio Telephone and Telegraph Company, U.S.A.

2343. **L. de Forest.** Broadcasting News by Radio Telephone. (*Electrical World*, 77, p. 936, April 23rd, 1921.)

Correspondence with regard to the advantages of broadcasting music, news, etc., by radio telephone in isolated districts.

2344. Wireless to Aid Load Dispatching of Southern Interconnection. (*Electrical World*, 77, p. 900, April 16th, 1921. *Technical Review*, 9, p. 158, June 7th, 1921—Abstract.)

Refers to the installation of two wireless stations for inter-communication between different companies interconnected with the power system of the Georgia Railway and Power Company.

2345. **Gesellschaft für drahtlose Telegraphie.** Wireless Signalling in Mines. (*British Patent* 158907, February 9th, 1921. Convention date February 9th, 1920. Patent not yet accepted.)

2346. **T. S. Casner** and **O. L. Badger.** Radio Controlled Clock. (*Journal of the American Institute of Electrical Engineers*, 40, p. 461, June, 1921.)

A short note referring to a master clock at Plainfield, N.J., which is automatically corrected by the radio time signals sent out daily from Washington. The corrective impulses also act on a number of secondary dials connected to the master clock.

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2347. **G. Ferrie.** A Note of the Methods Used for the Determination of Longitude by Radiotelegraphy. (*Monthly Notices of the Royal Astronomical Society*, 80, pp. 669—679, May, 1920.)

Gives a detailed description of the apparatus used by the Bureau de Longitude for the longitude determinations between Paris and Annapolis.

2348. **R. A. Sampson.** Determination of Longitude by Wireless Telegraphy. (*Monthly Notices of the Royal Astronomical Society*, 80, pp. 659—669, May, 1920. *Scientific American*, 123, p. 297, September 25th, 1920.)

A short historical *résumé* of longitude determination and of the importance of wireless for such work. Curves are given of the errors of standard clocks and the mapping out of the earth into zones for longitude determination by wireless is dealt with.

2349. Across Arabian Desert. (*The Times*, No. 42778, p. 9, July 21st, 1921.)

Refers to the use of portable wireless apparatus in connection with the survey of the air route between Cairo and Bagdad.

2350. **U. Bianchi.** A New Land Wire and Radio Transmitter of Photographs. (*Radio News*, 2, p. 366, June, 1920.)

Circuit diagrams of the proposed arrangements are given in connection with a short description.

2351. **E. H. Shaughnessy.** Some Recent Wireless Literature. (*Electrician*, 86, pp. 745—746, June 17th, 1921.)

Contains reviews of Van der Bijl's "The Thermionic Vacuum Tube"; B. Leggett's "Wireless Telegraphy with Special Reference to the Quenched Spark System"; and H. Rein's "Radiotelegraphisches Praktikun."

2352. **B. Leggett.** Wireless Telegraphy. (*Engineering*, 111, p. 658, May 27th, 1920.)

Correspondence with regard to a review of his book on wireless telegraphy.

2353. **J. Sayers.** Nomenclature for Wired Wireless. (*Electrician*, 86, p. 133, January 28th, 1921.)

Correspondence with regard to the best term to employ for describing high-frequency telephonic communication along wires.

2354. **G. O. Squier.** A Question of Nomenclature—Wire Radio. (*Electrician*, 85, pp. 716—717, December 17th, 1920.)

Correspondence as to the most suitable term to describe telegraphic and telephonic communication over wire by means of high-frequency currents. The term "wire radio" is suggested as the most comprehensive and useful. (See below.)

2355. **W. H. Eccles.** A Question of Nomenclature and Wire Radio. (*Electrician*, 86, p. 81, January 14th, 1921.)

Further correspondence on the question of nomenclature for high-frequency telegraphy and telephony having wires. The terms "Kumagrophy" or "Cymography" and "Cymoline" derived from the Greek words for a wire and a wave—Kuma and Linon—are suggested. (See RADIO REVIEW Abstracts Nos. 2354 and 2356 in this issue.)

2356. **R. D. Duncans, A. Press, L. Cohen, M. Latour.** A Question of Nomenclature—Wire Radio. (*Electrician*, 86, p. 56, January 7th; p. 305, March 11th; and p. 330, March 18th, 1921.)

Further suggestions for nomenclature. (See RADIO REVIEW Abstracts Nos. 2354 and 2355.) The terms multiple frequency wire telephony or telegraphy, carrier wave Morse system, carrier wave Squier system, line radio telegraphy and telephony and Squier telegraphy are suggested.

2357. Vacuum Tube Nomenclature. (*Radio Nieuws*, 4, pp. 108—109, April, 1921.)

See RADIO REVIEW, 1, p. 437, June, 1920.

2358. Electrolytic Cell Oscillations. (*Wireless Age*, 8, p. 19, January, 1921.)

An arrangement is described in which electrolytic cells containing aluminium electrodes are employed for the direct generation of high-frequency currents, the insulating barrier which is formed on the surface of the electrodes by the electrolytic action is intermittently broken down, and the impulse thus produced sets up high-frequency oscillations which may

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be coupled directly to the transmitting aerial circuit. Two cells are employed connected up, so that when the barrier in one cell breaks a high potential impulse is impressed on the second cell by means of a transformer to cause the breakdown of the barrier in that cell. A steady series of oscillations is thus produced.

2359. **R. I. Zalkind.** High Frequency Currents. (*French Patent* 504407, September 25th, 1919. Published July 5th, 1920.)

The specification describes an apparatus for the production of high-frequency currents to be employed for physiological purposes. The novel feature consists in collecting the apparatus in a single unit. The transformer secondary is connected to the terminals of the spark gap and with the primary circuit of a solenoid, which circuit is connected to condensers. The secondary of the solenoid is divided into sections and includes a switch permitting regulation of the high-frequency currents.

2360. **S. Loewe.** Röntgen Ray Apparatus. (*British Patent* 149013, July 12th, 1920. Convention date March 5th, 1919. Patent not yet accepted.)

Relates to the use of H.F. currents for exciting X-ray tubes.

2361. **J. Bethenod.** Railway Signals. (*British Patent* 159471, February 23rd, 1921. Convention date February 24th, 1920. Patent not yet accepted.)

Relates to the use of high-frequency currents generated on the train for railway signalling purposes.

2362. **Gesellschaft für drahtlose Telegraphie.** Locating Conductors by Wireless. (*British Patent* 147440, July 7th, 1920. Convention date November 23rd, 1917. Patent not yet accepted.)

For locating hidden conductors such as buried cables a coil with a strong leakage field is associated with an oscillation-generating thermionic valve. A conductor in the vicinity of the coil will then affect the frequency of the oscillations.

2363. **R. T. Lattey.** The Dielectric Constants of Electrolytic Solutions. (*Philosophical Magazine*, 41, pp. 829–848, June, 1921.)

Criticises the methods usually employed, and describes an apparatus and method using H.F. currents for this purpose. A bibliography of literature on the subject is appended to the article.

2364. **E. C. Hanson.** Apparatus for Locating Buried Ore. (*British Patent* 154534, November 23rd, 1920. Convention date May 7th, 1919. Patent not yet accepted.)

2365. **W. L. Carlson** (E. C. Hanson). Electromedical Apparatus. (*British Patent* 154535, November 23rd, 1920. Convention date July 12th, 1919. Patent not yet accepted.)

Deals with the use of valves for generating H.F. currents for electromedical purposes.

(A.) General Descriptive Articles of Installations, etc.

(1) Land Stations.

2366. **H. Thurn.** The Poulsen Arc Plant at Königswusterhausen. (*Radio Nieuws*, 4, pp. 35—45, February 1st, 1921. Also *L'Elettrotecnica*, 8, pp. 228—229, April 5th, 1921—Abstract. *Technical Review*, 7, p. 290, November 30th, 1920—Abstract. *Radioélectricité*, 1, p. 59D, November, 1920—Abstract. *Science Abstracts*, 24B, p. 317, June 30th, 1921—Abstract.)

A translation of the article referred to in Abstract No. 1056, November, 1920.

2367. **H. de la Noë.** The Lafayette (Bordeaux) Station—Construction of Foundations and Calculation of Stresses in Towers. (*Génie Civil*, 79, pp. 32–35, July 9th, 1921, pp. 53–57, July 16th, 1921.)

2368. **S. C. Hooper.** The Lafayette Radio Station. (*Electric Journal*, 28, pp. 112—113, April, 1921.)

An illustrated description.

2369. Wireless Telegraphy at Ushant. (*Radioélectricité*, 1, pp. 425–431, February, 1921.)

An illustrated description of the installations.

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2370. The Easthampton Radio Station. (*Technical Review*, 9, p. 79, May 3rd, 1921—Abstract. *Q.S.T.*, 4, p. 25, January, 1921—Abstract.)
See RADIO REVIEW, 2, pp. 66—68, February, 1921.

2371. The Nauen High Power Radio Station. (*Schweizerische Bauzeitung*, 76, p. 174, October 9th, 1920. *Revue Générale de l'Électricité*, 9, p. 37D, January 29th, 1921—Abstract.)
An account of the station and of its official opening last year.

2372. The High Power Radio Stations of the World. (*Schweizerische Bauzeitung*, 76, p. 174, October 9th, 1920. *Revue Générale de l'Électricité*, 9, p. 37D, January 29th, 1921—Abstract.)
Gives a list with particulars of twenty-four of the largest radio stations in the world.

2373. The Lafayette Radio Station at Croix d'Hin near Bordeaux. (*Revue Générale de l'Électricité*, 9, pp. 430—433, March 26th, 1921.)
An illustrated description of the station extracted from previously published articles.*

2374. **A. Gradenwitz.** Inauguration of the Extended Nauen Wireless Station. (*Electrician*, 85, p. 714, December 17th, 1920. *Revue Générale de l'Électricité*, 9, p. 207D, June 25th, 1921—Abstract. *Radioélectricité*, 1, p. 119D, April, 1921—Abstract.)
A short account of the Nauen station with illustrations of the mast base and anchorages. (See also RADIO REVIEW Abstract No. 1549, March, 1921.)

2375. A Few Ideas for Amateur C. W. (*Q.S.T.*, 4, pp. 5—9, September, 1920.)
A description is given of the valve transmitting equipment installed at the N.S.F. radio station of the Naval Air Service Radio Laboratory at Anacostia.

2376. **H. Sauve.** The High Power Radio Station at Kamina. (*Radioélectricité*, 1, pp. 493—496, March, 1921.)
An illustrated description of the construction of the station.

2377. **H. MacCallum.** Recent Commercial Developments in Wireless. (*Radio Review*, 1, pp. 685—694, November, 1920. *Radioélectricité*, 1, p. 91D, February, 1921. *Technical Review*, 9, p. 158, June 7th, 1921—Abstract.)

2378. **G. E. Hyde.** Commercial Radio Telephony at Avalon, Santa Catalina Island. (*Radio News*, 2, pp. 598 and 638, March, 1921.)
An illustrated description of the equipment and arrangements used for this radio telephone link between Santa Catalina Island and the mainland. Elevated aerials are used for transmission and loop aerials for reception in each case.

2379. **H. Thurn.** The Poulsen Arc Equipment at Königswusterhausen. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, p. 194—217, March, 1921.)
A descriptive account with photographs containing nothing beyond what has already been described. (See RADIO REVIEW Abstract No. 1056, November, 1920.)

2380. **E. F. Huth.** High-frequency Electric Signalling. (*British Patent* 149011, July 12th, 1920. Convention date December 31st, 1917. Patent not yet accepted.)
Describes a radio telephone apparatus adapted for intercommunication between the different rooms of a large building, using the plate circuit inductance of the oscillating valve as the frame aerial, and having a different wavelength allotted to each room. A push button selector may be used for varying the wavelength and so selecting the desired room. The whole apparatus is fed from the supply mains, for both L.T. and H.T. circuits, and the large resistance for the filament circuit may be included inside the bulb of the valve. The microphone is shown joined in the grid circuit of the valve, and the receiving telephones in the plate circuit.

2381. **J. Mayer** and **L. Hogelsberger.** The High Power Station of Deutsch-Altenburg. (*Electrotechnik und Maschinenbau*, 39, pp. 2—9, January 2nd, 1921.) *Electrical World*, 77, p. 724, March 26th, 1921—Abstract.)
A descriptive article with photographs and diagrams of the antenna arrangement and transmitting circuits.

2382. **E. C. Hanson.** Wireless Distribution of Music. (*British Patent* 156769, January 7th, 1921. Convention date June 3rd, 1918. Patent not yet accepted.)
Relates to an "electrostatic" type of transmitter.

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* See RADIO REVIEW Abstracts Nos. 1423 and 1425, February, 1921.

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2383. **A. Bidault des Chaumes.** Arc *versus* Alternator for High Power Work. (*Radio Review*, 2, pp. 199—201, April, 1921. *Bulletin de la Societe Belge des Électriciens*, 35, pp. 124—125, May-June, 1921.)

2384. **E. H. Shaughnessy.** Imperial Wireless Station at Leafield, Oxfordshire. (*Post Office Electrical Engineers' Journal*, 14, pp. 79—89, July, 1921.)
An illustrated description of the station buildings, plant and apparatus.

2385. The Californian Theatre Radio Station. (*Radio News*, 2, p. 857, June, 1921.)
An illustrated description.

2386. **S. R. Winters.** The Washington Air Mail Radio Station. (*Radio News*, 2, p. 860, June, 1921.)
A short illustrated description of the installation.

2387. Carnarvon. (*Aire, Mar y Tierra*, 2, pp. 75—80, February, 1920.)

2388. The Spanish Central Meteorological Office. (*Aire, Mar y Tierra*, 2, pp. 451—457, August, 1920.)
An illustrated description of the wireless equipment.

2389. **M. Verdier.** The Radio Stations of the French Postal Telegraph Administration. (*Annales des Postes, Télégraphes et Téléphones*, 10, pp. 303—315, June, 1921.)
An historical *résumé* of the development of the various French coast stations and of the changes in the apparatus used therein. The high power and transatlantic stations are also considered.

2390. Radio Service between Rotterdam and Germany. (*Radio Nieuws*, 4, pp. 167—170, June 1st, 1921.)
A short account with photographs of the installation at the Central Telegraph Office in Rotterdam. Valve transmitters are employed.

2391. **Dr. Verch.** The Telefunken Valve Transmitter at Königswusterhausen. (*Radio Nieuws*, 4, pp. 179—182, June, 1921.)
A short account of the 10 kW set consisting of six valves in parallel supplied with anode current at 4,800 volts. This set is employed for the high-speed communication with Stonehaven.

2392. The Radio Station at Eilvese (Hanover). (*L'Elettrotecnica*, 8, pp. 137—139, February 25th, 1921.)
An illustrated description.

2393. **R. W. Goddard.** New Mexico State College Radio Station. (*Radio News*, 2, p. 292, November, 1920.)
A short illustrated description.

2394. The Eiffel Tower Radio Station. (*Radio News*, 2, pp. 350—352, December, 1920.)
An illustrated description of the equipment including the time signalling apparatus.

2395. The Lafayette Radio Station. (*Radio News*, 2, pp. 510—512, February, 1921.)
An illustrated description. (See also RADIO REVIEW Abstracts Nos. 1425, February, 1921, and 2373.

(2) SHIP INSTALLATIONS.

2396. **H. R. Rivers-Moore.** Some recent Designs for Ship Radio Installations. (*Radio Review*, 2, pp. 172—179, April, 1921.)

2397. **H. MacCallum.** Wireless in the Mercantile Marine. (*Electrician*, 85, pp. 263—266, September 3rd, 1920; *Revue Générale de l'Électricité*, 9, p. 15D, January 8th, 1921—Abstract.)
An illustrated description of various types of apparatus manufactured by Marconi's Wireless Telegraph Company.

2398. Radio Telephony on Fishing Vessels. (*Radioelectricité*, 1, p. 549, April, 1921.)
An illustrated description.

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2399. **de Bouillane.** Wireless and the Mercantile Marine. (*Radioélectricité*, 1, pp. 574—578, May, pp. 623—628, June, 1921.)
A continuation of the description in Abstract No. 1769, May, 1921. The Telefunken apparatus and the installations of the Société Française Radioélectrique are described and illustrated.

2400. Radio Apparatus for the Mercantile Marine. (*Electrician*, 86, pp. 722—725, June 10th, 1921.)
An illustrated description of some of the apparatus manufactured by Messrs. R. M. Radio, Ltd. A new design of triode valve, using a hemispherical grid and anode, is also briefly described and illustrated.

2401. **R. E. Lacault.** The Audio Frequency Amplifier in France. (*Science and Invention*, 8, pp. 1317—1318, April, 1921.)
A short illustrated article giving circuit diagrams of various patterns of French army amplifiers.

2402. Some Modern Improvements in Radio Installations for Ships. (*Electrician*, 86, pp. 49—51, January 7th, 1921; *Radioélectricité*, 1, p. 127D, May, 1921—Abstract.)
An illustrated description of the $1\frac{1}{2}$ and $\frac{1}{4}$ kW ship installations manufactured by the Radio Communication Co., Ltd.

2403. A New 3 kW Panel Transmitter. (*Radio News*, 2, p. 515, February, 1921.)
A short illustrated note describing apparatus manufactured by the **Wireless Speciality Company.**

(3), (4) AND (5) AIRCRAFT AND PORTABLE INSTALLATIONS.

2404. **R. H. Barfield.** Commercial Progress in Aircraft Wireless. (*Radio Review*, 2, pp. 4—14, January, 1921. *Science Abstracts*, 24B, p. 210, Abstract No. 425, April 30th, 1921—Abstract.)

2405. **M. Bernard.** The Present Position of Wireless in Aviation. (*Radioélectricité*, 1, pp. 523—532, April; pp. 579—586, May; and pp. 613—623, June, 1921.)
A detailed description of different types of apparatus used in French aircraft with many illustrations of gear manufactured by the Société Française Radioélectrique.

2406. **E. F. Huth.** Wireless Apparatus for Aeroplanes. (*British Patent* 148804, July 10th, 1920. Convention date September 8th, 1916. Patent not yet accepted.)
In order to reduce the number of operations required to bring an aeroplane or like wireless set into operation a lever is provided so that when moved in one direction the generator is coupled to the engine shaft and a motor is started up to unwind the aerial. On reversing the movement of the lever the generator is disconnected and the aerial reel motor reversed to pull in the aerial wire.

2407. **C. K. Chandler.** Wireless Apparatus on Aircraft. (*British Patent* 160502, November 24th, 1919. Patent accepted March 24th, 1921.)
In receiving apparatus interference from a magneto or other disturbing source is obviated by a corrector circuit containing inductance and capacity, the inductance of which is coupled to the disturbing source so that the energy picked up by the corrector circuit neutralises that picked up by the receiving circuit.

2408. **E. F. Huth.** Aircraft Wireless Apparatus. (*British Patent* 148323, July 9th, 1920. Convention date December 4th, 1914. Patent not yet accepted.)
Relates to a subdivision of aircraft wireless transmitting apparatus into separate units.

2409. A Marconi Wireless Telephone Set for Aircraft. (*Electrical Review*, 88, pp. 832—833, June 24th, 1921.)
A short illustrated description of some aircraft wireless apparatus manufactured by Marconi's Wireless Telegraph Company. (See RADIO REVIEW, 2, pp. 4—14, January, 1921, for description of the same apparatus.)

2410. **Gesellschaft für drahtlose Telegraphie.** Railway Signals. (*British Patent* 147445, July 7th, 1920. Convention date February 4th, 1919. Patent not yet accepted.)
An oscillation generator carried on the train co-operates with a tuned circuit on the track

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in such a way that when the track circuit draws energy from the train circuit the relay releases its armature and puts the signal apparatus on the train into operation.

2411. **C. A. Oliver.** Handcart for Transporting Wireless Apparatus. (*British Patent* 154637, May 13th, 1919. Patent accepted December 9th, 1920.)

2412. **E. F. Huth.** Portable Wireless Apparatus. (*British Patent* 148317, July 9th, 1920. Convention date October 30th, 1913. Patent not yet accepted.)

Separate carrier frames for portable wireless apparatus may be united together to form a rigid framework for operating the set.

2413. **E. Nesper.** Wireless Stations in Competition with Wire and Cable Telegraphy. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, pp. 69–72, January, 1920. *Science Abstracts*, 24B, p. 214, Abstract No. 432, April 30th, 1921—Abstract.)

(6) GENERAL AND POPULAR RADIO ARTICLES.

2414. The Future of Radiotelegraphy. (*Telegraph and Telephone Age*, 39, p. 157, April 1st, 1921.)

2415. **E. T. Fisk.** The Practical Application of the Triode Valve in Radio Communication. (*Sea, Land and Air*, 3, pp. 769–779, March 1st, 1921.)

A paper read before the Australasian Association for the Advancement of Science in January, 1921, and describing recent advances in the applications of valves. Some commercial valve apparatus manufactured by the Marconi and Associated Companies is illustrated.

2416. German Wireless Telegraphy. (*Telegraph and Telephone Age*, 39, p. 179, April 16th, 1921.)

A short note with regard to the leading German radio installations.

2417. Progress of Wireless Telegraph at the Brussels Commercial Fair. (*L'Électricité pour Tous*, 3, p. 117, April 30th, 1921.)

A short account of some of the wireless apparatus on exhibition.

2418. **E. W. Marchant.** Modern Developments in Wireless Telegraphy and Telephony. (*Electrician*, 86, p. 464, April 16th, 1921.)

A short abstract of a lecture delivered at the Municipal College of Technology dealing in particular with the progress in thermionic valve apparatus in wireless telephony and directional wireless.

2419. Radio Telegraphy at the Paris Fair, 1921. (*Radioélectricité*, 1, pp. 608–609, May, 1921.)

Illustrations are given of the exhibits by the Société Française Radioélectrique.

2420. **J. H. Dellinger.** Radio Communication. (*Radio News*, 2, pp. 678–679, April, 1921.)

An elementary explanation of the principles of radiotelegraphy and telephony.

2421. **H. Eales.** Wireless Telephony. (*Zentralzeitung für Optik und Mechanik*, 41, p. 69, 1920.)

2422. **M. Revol.** Wireless Telegraphy. (*L'Électricité pour Tous*, 3, pp. 148–152, May 31st, 1921.)

Paper read before the Association Technique des Électriciens.

2423. **L. H. Rosenberg.** A New Era in Wireless. (*Scientific American*, 124, p. 449, June 4th, 1921.)

A short article describing the uses of radiotelephony for broadcasting news, music and sermons.

2424. Broad Street, New York, as a Cabling Radio Centre. (*Telegraph and Telephone Age*, 39, p. 212, May 1st, 1921.)

A short article dealing with the concentration of cable and radio offices in Broad Street, New York.

2425. **W. H. G. Bullard.** The Application of Radio to Navigation Problems. (*Journal of the Franklin Institute*, 191, pp. 725–766, June, 1921.) *Electrical World*, 78, p. 131, June 16th, 1921—Abstract.)

The full paper to which reference has already been made in Abstract No. 1786, May, 1921. The author briefly described and illustrated the New York Radio Central Control Station,

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summarised the transmission of time signals from the high-power naval radio stations of the United States, described the weather reports that are issued from various radio stations on the United States coast and then proceeded to detail the application of direction-finding work to navigation problems. The United States radio compass apparatus is described and illustrated, and some interesting comparisons given in the form of charts of positions as determined by the radio compass bearings and the actual positions and courses of vessels. The application of pilot cables to guiding ships into harbours is described and the acoustic methods of determining the depth of water under the vessel. A chart is given of the International Meteorological Service detailing the weather reports issued by various wireless stations in the world. Some samples of records obtained with high-speed transatlantic reception are also included.

2426. Chicago Police use Radiophone. (*Science and Invention*, 9, p. 246, July, 1921.)

2427. **J. Slepian.** Why High Frequency for Radiation ? (*Electric Journal*, 28, pp. 129–131, April, 1921. *Electrical World*, 77, p. 1175, May 21st, 1921—Abstract.)

The author attempts to show in a qualitative way how the introduction of Maxwell's displacement currents combined with the previously held laws of electromagnetism explain the fact that electric and magnetic fields are propagated with a finite velocity.

2428. **E. F. W. Alexanderson.** Notes on Wireless. (*Annales des Postes, Télégraphes et Téléphones*, 10, pp. 364–367, June, 1921.)

A report of an address delivered to the French delegates visiting the Radio Corporation of America in October, 1920.

2429. **W. Lebrenz.** The Berne Directory of Wireless Stations (*Telefunken Zeitung*, 4, pp. 26–31, March, 1921). The author describes his feelings on turning over the pages of the 6th edition and looking for the names of ship and land stations which were once German and Austrian. He says "Sic transit gloria mundi," but calls upon his colleagues to see that the next edition shows Germany again taking her old place.

2. Books.

WIRELESS DESIGN AND PRACTICE. Part I.: TRANSMITTERS AND RECEIVERS. Part II.: PRACTICAL CIRCUITS. By M. B. Sleeper. (London: *Henry Frowde and Messrs. Hodder and Stoughton*. 1920. Pp. 246. $7\frac{1}{2}'' \times 5''$. Price 7*s.* 6*d.* net.)

This work differs from most books on wireless subjects in that it is not a general text-book of the usual type, nor is it a text-book simplified for the amateur, but it is a book devoted entirely to the practical design of wireless apparatus, setting out in the simplest manner the principles of design of the various pieces of wireless apparatus required by the amateur or experimental wireless station. Very little mathematics is used—not more than required for the numerical calculation of dimensions from simple formulæ and tables of factors.

The first part of the book deals with the following items: Oscillating Circuits—Aerials—Design of Receiving Inductances—Design of Receiving Condensers—Valve Detecting Circuits—Oscillating Valve Circuits and Undamped Wave Receivers—Damped Wave Transmitters—and Vacuum Tube Transmitters.

The methods of calculation are set out quite clearly with as little as possible of descriptive padding—and it is assumed throughout that the reader is familiar with at least the general features of the apparatus dealt with. A few useful plates are inserted giving the general appearance of complete instruments and parts.

The second part of the book contains 86 circuit diagrams, each accompanied by a few explanatory notes and dimensions, of various simple arrangements for transmitting and receiving.

A few minor blemishes have been noted but in other respects the book is well prepared. The most serious defect from the point of view of the English reader is the use throughout of "B & S" gauge sizes for wires, without the inclusion of any table of comparison with S.W.G. In some cases in the text B & S gauge is apparently assumed, but is not so labelled. This omission might lead to confusion in the construction of apparatus.

PHILIP R. COURSEY.

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THE "PRACTICAL ENGINEER" ELECTRICAL POCKET BOOK AND DIARY FOR 1921. (London: *The Technical Publishing Co., Ltd.* 1921. Pp. ciii + 610 + 48. $5\frac{1}{4}'' \times 3\frac{1}{4}''$. Price 2*s.* 6*d.* net. Post free 3*s.* Abroad 3*s.*)

As compared with the previous edition of this useful pocket book, the wireless notes in the current issue have been considerably revised and improved, and in particular those relating to the Marconi Company's apparatus have been augmented. The three-electrode valve and its uses is now given more adequate treatment, but for other apparatus—arc and quenched spark transmitters, etc.—the reader is referred to text-books. The list of Wireless Text-books that was previously issued has apparently not been revised, but has been omitted entirely, and its place filled with a short section on Wireless Telephony containing a description of the arrangements for use in aircraft.

P. R. C.

Books Received.

PRINCIPLES OF RADIO COMMUNICATION. By J. H. Morecroft (Assistant Professor of Electrical Engineering, Columbia University), assisted by A. Pinto and W. A. Curry. (New York: *John Wiley & Sons, Inc.* London: *Chapman & Hall, Ltd.* 1921. Pp. x + 935. 9" × 6". Price 45*s.* net.)

THERMIONIC TUBES IN RADIO TELEGRAPHY AND TELEPHONY. By John Scott-Taggart, A.M.Am.I.E.E. (London: *The Wireless Press, Ltd.* 1921. Pp. xxiii + 424. $8\frac{1}{2}'' \times 5\frac{1}{2}''$. Price 25*s.* net.)

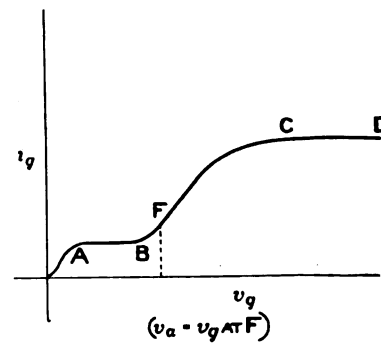
THE ALEXANDERSON SYSTEM FOR RADIO TELEGRAPH AND RADIO TELEPHONE TRANSMISSION. By Elmer E. Bucher. (New York: *Wireless Press, Inc.* 1920. Pp. 55. $10\frac{3}{4}'' \times 8''$. Price 10*s.* 6*d.* net.)

Correspondence.

TRIODE CHARACTERISTICS WITH HIGH GRID POTENTIAL.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—It is clear from the communications of Dr. van der Pol and Mr. Bartlett that secondary electronic emission from both the grid and the anode of a triode tube occurs at high potentials and plays an important part in the action of high voltage triode generators. It can, however, be shown that secondary electrons from the anode are produced in low voltage circuits (*e.g.* with anode potentials of 10 volts) and can be detected whenever the grid potential approaches that of the anode. It seems that the usual explanations of the form of low voltage triode characteristics in the region where the grid potential v_g is greater than the anode potential v_a are erroneous and that the portion BC of the grid characteristic shown in the diagram is really the characteristic of a diode consisting of the anode as source of electrons and the grid as collecting electrode. The usual explanation is that the sudden increase in grid current is due to the deviation of electrons from the primary stream to the anode, but the difficulty with such an interpretation is to explain the constancy of the grid current in the regions AB and CD. If we adopt the new interpretation these difficulties disappear.



E. V. APPLETON.

Cambridge.
July 16th, 1921.

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THE RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

VOL. II OCTOBER, 1921 NO. 10

Editor :
PROFESSOR G. W. O. HOWE, D.Sc., M.I.E.E.
Assistant Editor :
PHILIP R. COURSEY, B.Sc., F.Inst.P., A.M.I.E.E.

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Editor: Prof. G. W. O. HOWE, D.Sc., M.I.E.E. Asst. Editor: PHILIP R. COURSEY, B.Sc., A.M.I.E.E.

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Editorial.

The Effect of Atmospherics on the Choice of Wavelength.—It was discovered very early in the development of radiotelegraphy that as the receiving aerial was tuned to longer and longer wavelengths, the disturbances due to atmospherics steadily increased, indicating that if they possessed any frequency it was relatively low. No indication of any definite frequency has been found, however, and it is now generally assumed that atmospheric disturbances are due to heavily damped non-oscillatory electromagnetic pulses. This was the assumption made by Abraham in his paper in the *Jahrbuch* in 1919 in which he discussed the reason for the frame or coil aerial being less susceptible to atmospheric disturbances than the open antenna. In the present issue we publish a paper by Mr. L. B. Turner, in which he applies Abraham's formulæ to the calculation of the optimum wavelength to employ over any given range so as to obtain not the maximum received power, but the maximum ratio of signal to atmospheric. This leads to much shorter wavelengths than are obtained from consideration of the power only.

That this is a matter of the greatest importance is evident to any one acquainted with the operation of long-distance stations at the present day. When messages cannot be received it is not as a rule due to the signals being too weak, but to the atmospherics being too strong.

May it not be that the makers of high-frequency alternators and arcs, with the help of the promise held out by the Austin-Cohen formula, have tempted us too far in the direction of long wavelengths? It would appear so, unless some really effective anti-atmospheric device can be devised and thus remove what is undoubtedly the most serious limitation to long-distance radiotelegraphy. [3593]

Recent Improvements in the Poulsen Arc.—Professor P. O. Pedersen, who has done so much to throw light on the operation of the Poulsen arc under practical conditions, has recently published * an interesting account of an improvement which he has introduced. This consists of a water-cooled copper saddle resting on the carbon cathode a short distance from the striking edge. In each cycle the arc strikes between the nearest points of

* *Electrician*, 86, pp. 684—686, June 3rd, and pp. 714—716, June 10th, 1921.

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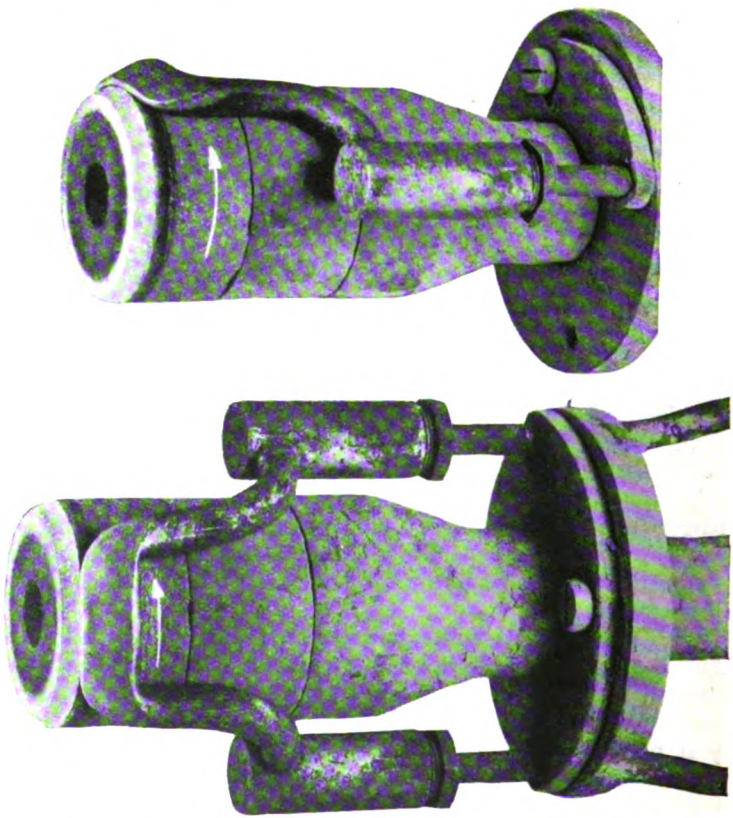
the electrodes, is driven upwards and outwards by the magnetic field until it is extinguished. If working normally it should then restrike at the original points, but if the field be too weak it will restrike as a long arc where it has just been extinguished and continue to be blown still further during the succeeding cycle, which is thus not an exact repetition of the first cycle.



Two views of Professor Pedersen's Water-cooled Arc Saddle.

With still weaker fields three or four cycles may elapse before the arc ceases its outward travel and restrikes at the nearest points of the electrodes. This irregularity of successive cycles can be prevented by suitably increasing the field, which must not be made too strong, however, since this would lead to reduced efficiency.

The addition of the water-cooled saddle causes the arc to extinguish on reaching it and to restrike at the nearest points of the electrodes even with a magnetic field too weak to give this ideal operation when the water-cooled saddle is not fitted. Professor Pedersen has given oscillograms and photo-

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graphs proving conclusively that the arc does work in this way. He states, however, that no great increase in the efficiency was obtained directly by the use of the cooling saddle. The photographs give a clear idea of the construction of the saddle which is held stationary whilst the carbon electrode is rotated.

The British Association.—Elsewhere in this issue will be found an account of some experiments carried out by Mr. A. A. Campbell Swinton on Shielded Frame Aerials. These were described in a paper read before Section A of the British Association for the Advancement of Science, which met this year at Edinburgh, between September 7th and 14th, under the Presidency of Sir T. Edward Thorpe, C.B., D.Sc., F.R.S. Other papers of wireless interest read before the Association will be dealt with in our next issue.

Wireless Telegraphy in Western Australia.

By R. C. GRAY, M.A., D.Sc.

Western Australia is a land of large spaces, and seems to the writer to have an enormous opportunity for both amateur and professional wireless telegraphy and telephony. Unfortunately the isolated position of the State, away from the markets of the world, prevents those interested here from realising the strides the science has made in recent years, and business firms at home from appreciating the scope there is for the development of their business in the State.

The amateurs are mostly settled round Perth, the capital city, built on a soil consisting chiefly of yellow sand. This sand stretches inland to the Darling Range, beyond which is the great tableland of the interior, from 1,000 to 2,000 feet above sea level, and the difficulty of getting a proper earth in the sandy soil, which in summer dries to several inches below the surface, is considerable. The old "stand by," the water pipe, when used as an earth, introduces nightmares, of considerable intensity when the receiving gear is at all sensitive. The city has a widespread tramway system; this forms the second trouble. The local lighting system is by 250 volts A.C. electricity, borne far into the bush in every direction on wooden poles about 25 to 30 feet high. Owing to the rapid growth of the city in late years and the consequent overloading of the electrical generators, the voltage of the lighting supply is continually varying with the load, and the enthusiastic amateur hears most of these variations, in spite of all known precautions. In addition to these disturbances, we have atmospherics, especially in summer, of a strength seldom experienced in Great Britain. On the other hand, the only disturbing station is the Perth W.T. station (**VIP**), situated at Applecross, about five miles away, and working generally with ships on 600 metres spark; and an efficient receiving set tuned for long waves eliminates such signals completely. Amateurs listening on 600 metres have plenty of scope; a detecting valve with a leaky grid handles signals from **VIP** effectively, and is always ready for weak signals from distant ships. The promise of good research work by amateurs lies, however, in the use of long waves. There are no disturbing stations working on long

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waves, within hundreds of miles. The result is that, provided the night is quiet, European stations (8,000 miles away) on 10,000 metres and upwards are easily picked up. In March these signals begin to increase *slowly* in strength at about one hour after sunset here (seven hours before sunset at home), and reach a maximum about 1 a.m. (one hour before sunset at home); this maximum is retained until an hour after sunrise, after which the signals fade *very rapidly* to the day strength, although at this time the waves are travelling through seven hours (105°) of darkness and only one hour (15°) of light. Nauen (**POZ**) on 12,600 metres and Lyons (**YN**) on 15,500 metres are heard most easily, though the new station of Lafayette (**LAF**) has been heard more loudly at times. Eilvese (**OUI**) and Rome (**IDO**) are easily picked out; but on these long waves (12,000 to 20,000 metres) the overlapping becomes considerable, and the trouble of identifying the other weaker signals is very great. Probably the most interesting signals heard at night are from Annapolis (**NSS**) on about 17,000 metres. This station is about 11,600 miles from Perth, almost on the other side of the earth, the angle through which the direction of the waves changes being 167° 50'. Signals from **NSS** are most easily heard at night, but this may be due mainly to the stoppage of the local tramcars at midnight. During a tramway strike, the writer heard the time signals from **NSS** at 11 a.m. local time (0300 G.M.T.), easily readable, on an aerial of three parallel wires 30 feet high and 50 feet long, the receiving gear being two single layer inductances, loosely coupled, condensers about one jar, and a three-valve (two V24, one Q) radiofrequency amplifier. These signals are heard about the same strength with *one* valve on a neighbouring aerial 40 feet high and 160 feet long. It is worthy of note that low-frequency amplifiers are absolutely useless in low latitudes such as ours.

From the business point of view, the extensive spaces to the north and east badly need wireless telegraphy, or preferably telephony. The cost of running a telegraph line a few hundred miles for only one or two subscribers is prohibitive. Information published recently shows that the Australian Postmaster General's Department, in response to a request for telegraphic communication, proposes erecting wireless telegraph stations at Powell's Creek and Camooweal, these stations to be provided solely for the purpose of collecting traffic from private wireless stations in the scattered outlying districts. The estimated cost of erection of a telegraph line to serve these districts is £60,000, whereas the wireless stations will cost about £5,000. A similar scheme of private stations working with Government stations would be more easily developed in Western Australia, on account of the large number of Government stations already in existence here. There are apparently, however, no firms in Western Australia in a position to demonstrate the working of a wireless telegraph or telephone transmitting set, or to quote for such, and there seems to be an excellent opportunity in this connection, waiting for British firms. A set shown working at the Royal Agricultural Show, held annually in October and attended by pastoralists and agriculturists from all over the State, would open the market, and incidentally help in the development of Western Australia. **[4091]**

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The Opening of the Leafield Wireless Station.

Leafield, the first station of the British Imperial Wireless Chain, was formally opened for service on Thursday, August 18th, 1921. The long-drawn-out history of the British Imperial Wireless Scheme is too well known to need detailed repetition here, but it may be recollected that the plans for the erection of the station on this site date back to 1913 when a contract (subsequently cancelled) was made between the Post Office and Marconi's Wireless Telegraph Co., Ltd., for its erection as a 300 kW spark installation, together with other stations of the chain. The site chosen, Fig. 1, is high up

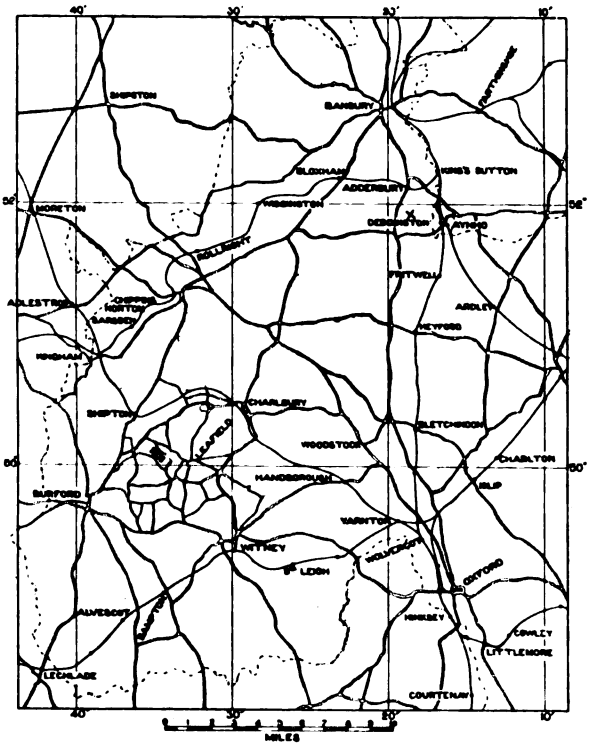

FIG. 1.—Map showing Site of Leafield Station and approximate position of proposed station near Banbury.

on the Cotswold Hills in Oxfordshire about 600 feet above sea level and the tubular steel masts form a landmark for many miles around. These masts, of which there are ten (Fig. 2), are each 300 feet high and were erected by the Marconi Company before the cancellation by the Post Office of the above-mentioned contract.

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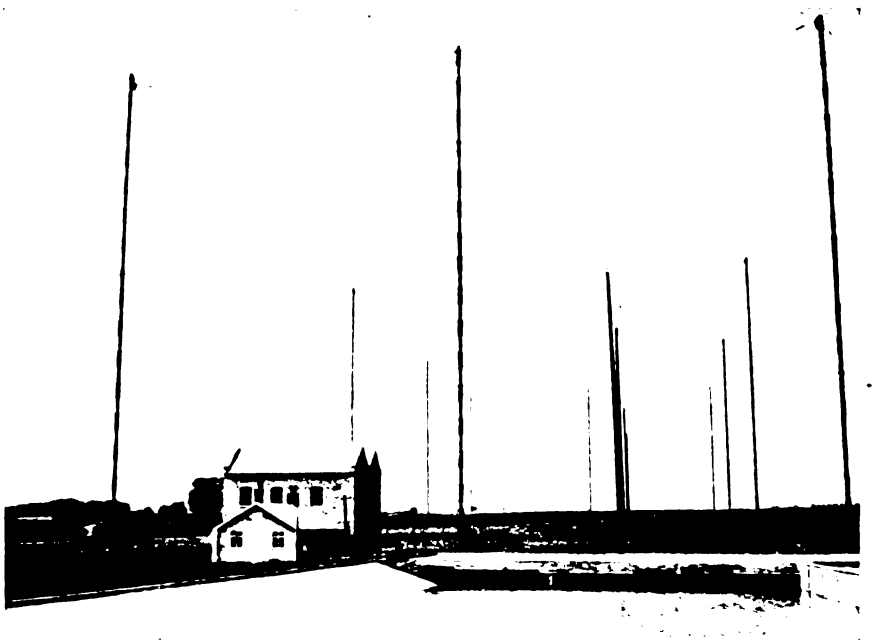
All the work on this station as regards its development for Imperial communications was suspended during the war, the masts, up till 1918, being merely utilised to support aerials for experimental reception. In the spring of 1919 the question of completing the English and Egyptian stations and of utilising the sites originally chosen for them came under review by the Imperial Communications Committee which had recently been instituted. In view of the very heavy pressure of traffic on the cables between England and Egypt it was decided to complete the stations, and Parliament sanctioned the estimated expenditure of £170,000 for this purpose in August, 1919. The scheme has been delayed by the numerous difficulties in the industrial world, with the result that the Leafield Station has only just been opened, while the Cairo station will not be ready until November.



[Photo: *Sport and General.*

FIG. 2.—General view of Leafield Station, showing Wireless Building.

The great development of continuous wave generators which has taken place in the period covered by the war made it clear that high power spark installations are now obsolete, so that the methods of generating high frequency continuous waves—the alternator, the timed spark and the Poulsen arc—which were then available were investigated by the Post Office. After a careful watch on the performance of various transatlantic services it was decided that the most suitable generator to use for these stations was the arc, and rough plans and estimates for the completion of the stations were prepared by the Post Office Engineering Department.

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To mark the historic occasion of the opening of the first station of the British Imperial Chain the ceremony was performed by the Postmaster-General, Mr. F. G. Kellaway, who was accompanied by a number of Post Office engineers and members of the Advisory Committee. Among the visitors were :—

Sir Thomas Williams, of the London and North-Western Railway, and Mr. Blakemore (members of the Post Office Advisory Committee); Admiral of the Fleet Sir Henry Jackson (Chairman of the Radio Research Board); Colonel Cusins (War Office Signals Experimental Establishment, Woolwich); Mr. O. F. Brown (Technical Officer of the Radio Research Board); Mr. S. C. Clements (representing Sir R. Jones, of Reuter's, a member of the Cable Users' Committee); Colonel Crawley (Deputy Inspector of Wireless Telegraphs, G.P.O.); Major Purves (Assistant Engineer-in-Chief, G.P.O.); Mr. E. H. Shaughnessy (Head of the Wireless Section, G.P.O.); and Mr. F. J. Brown (Assistant Secretary in Charge of Telegraphy, G.P.O.).

[Photo: *Sport and General.*

Fig. 3.—The Postmaster-General receiving the replies to the first messages sent out from Leafield Station.

After a tour of inspection of the buildings two messages were sent out, the first to all British stations in range, and the second to all European and other foreign stations in range. These messages ran as follows :—

(1) The Postmaster-General sends greetings to all British stations within range on the occasion of the completion of this, the first station of the Imperial wireless chain, and trusts that the station will help to knit still closer the bonds which bind together the different parts of the Empire.

(2) The Postmaster-General sends greetings to all European stations and to other foreign stations in range on the occasion of the completion of this, the first high-power station owned by the British Post Office, and trusts that the development of wireless communication will help to knit still closer the bonds of amity which bind the British Empire to all other States.

A few minutes after the second message had been despatched replies and acknowledgments were received from various European stations, including Rome, Budapest, Posen, Nauen, Malta and stations in France, Norway and Sweden (Fig. 3), the signals being reported as being clear and having a good note. Test signals have also been acknowledged from Gibraltar, Aden, St. John's, Newfoundland, Bermuda, and Jamaica.

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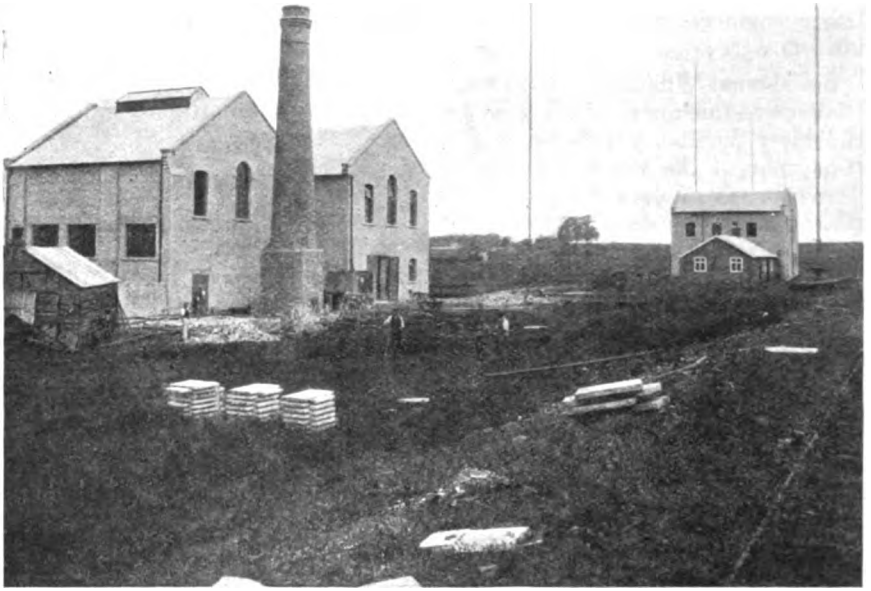
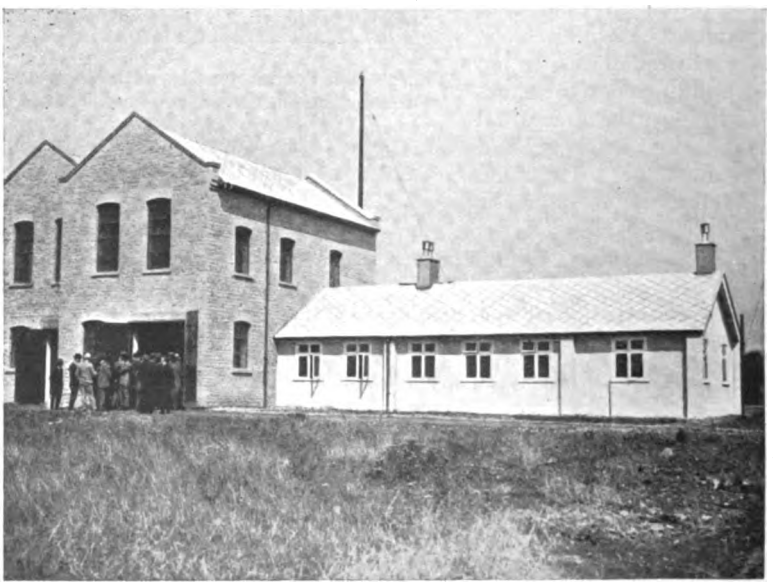


FIG. 4.—View of Power House with Wireless Building in background.



[Photo: *Sport and General.*

FIG. 5.—The Wireless Building at Leafield.

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The main buildings of the station are constructed of limestone quarried locally. They comprise the Power House (Fig. 4), containing the boiler room, turbine room, condenser room, workshop, offices, etc.; and the Wireless Building (Fig. 5), in which on the ground floor are the switch room, main store room and general offices, and on the first floor the arc room and the inductance room. The Wireless Building is separated from the Power House by a distance of 150 feet. On the site are also a number of bungalows (Fig. 6), for the accommodation of the station staff.

[Photo: *Sport and General.*

Fig. 6.—One of the Bungalows for the Station Staff.

In the boiler house two hand-fired Babcock and Wilcox boilers are installed, each unit being capable of meeting the demands of all the turbines. The working steam pressure is 200 lbs. per square inch with a superheat of 200° F. A brick shaft 60 feet high, and 4 feet internal diameter at the top, provides natural draught for the boilers, but a motor-driven Sirocco fan is also installed so that induced draught can be used if desired. The turbo-generators with their controlling switchboard, condensers, air pumps and other auxiliaries were installed by Messrs. W. H. Allen, Son & Co., Ltd. One of the units is shown in Fig. 7. Four turbo units are provided arranged in two sets for the generation of continuous current at 220 volts, and at 750 to 1,000 volts. These supplies are used for the auxiliary motors and lighting, and for the arcs respectively. The switching arrangements provide for the use of the duplicate sets (Fig. 8) for each voltage either singly or in parallel. The turbines are of the Curtis type and run at 6,000 r.p.m. They are geared down to 650 r.p.m. for the 1,000 volt generators, and to 1,000 r.p.m. for the 220

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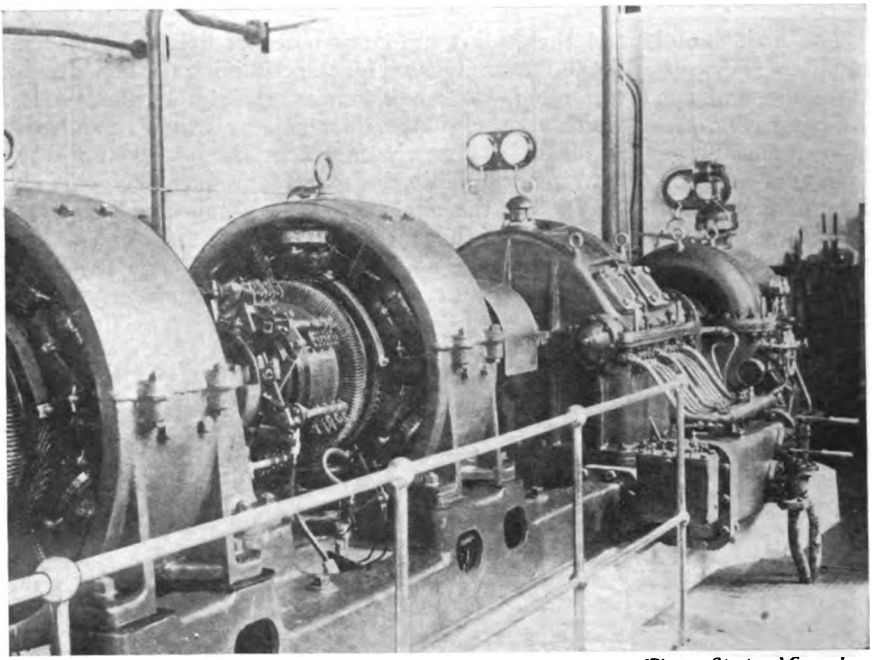

[Photo: *Sport and General.*

FIG. 7.—One of the 1,000-volt Turbo-generator Units.

volt machines. Each of the 1,000 volt 250 kW sets consists of two 500 volt machines mounted on the same shaft as may be seen from Fig. 7, and connected in series. These machines are each insulated from the bedplate and are connected by insulating couplings. The 220 volt units are of 60 kW capacity each and are compound wound. Cooling water for the condensers is obtained from a spring in a valley about one and a quarter miles distant from the wireless station. Motor driven pumps are used for pumping water up to the cooling pond near the Power House.

[Photo: *Sport and General.*

FIG. 8.—The Opening of Leafield Station. Inspection of turbo-generators, and showing relative position of the duplicate sets.

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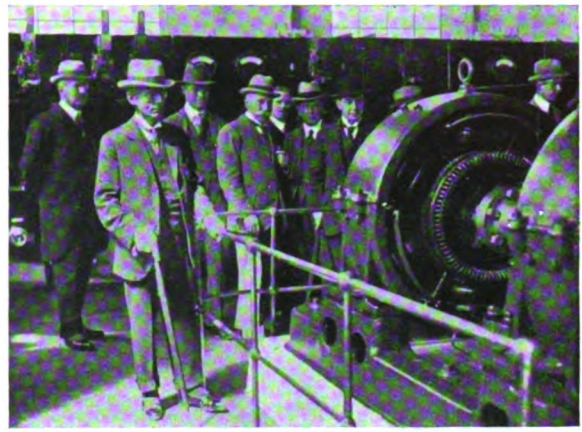
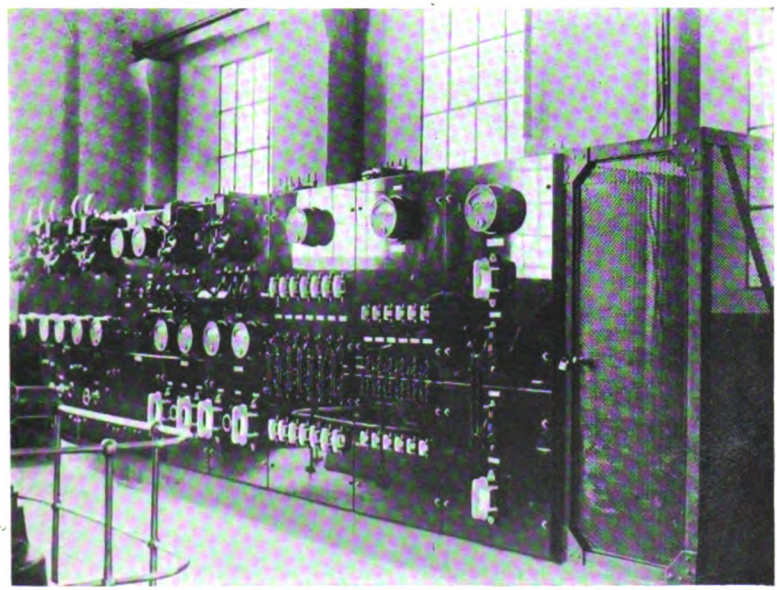
This pond has a capacity of about 1,000,000 gallons. A general view of the main switchboard which controls the whole of the energy generated in the station is shown in Fig. 10. Armoured cables are used to convey the current from it to the switch-room of the Wireless Building.



[Photo: *Sport and General.*

FIG. 9.—Turbo-generator, dynamo end, showing Switchboard in background.

In the Wireless Building itself the high frequency energy is generated by arc apparatus which is installed in duplicate. Each of the arc units is of 250 kW capacity and was manufactured by Messrs. C. F. Elwell, Ltd., who also supplied the necessary auxiliary equipment. One of the units may be seen in Fig. 11 and some of its component parts in course of construction at the works of that company in Fig. 12. In this illustration a few magnet coils can be seen on the right-hand side, a part of one of the arc chambers with cathode on the left of



[Photo: *Sport and General.*

FIG. 10.—The Main Switchboard at Leafield Station.

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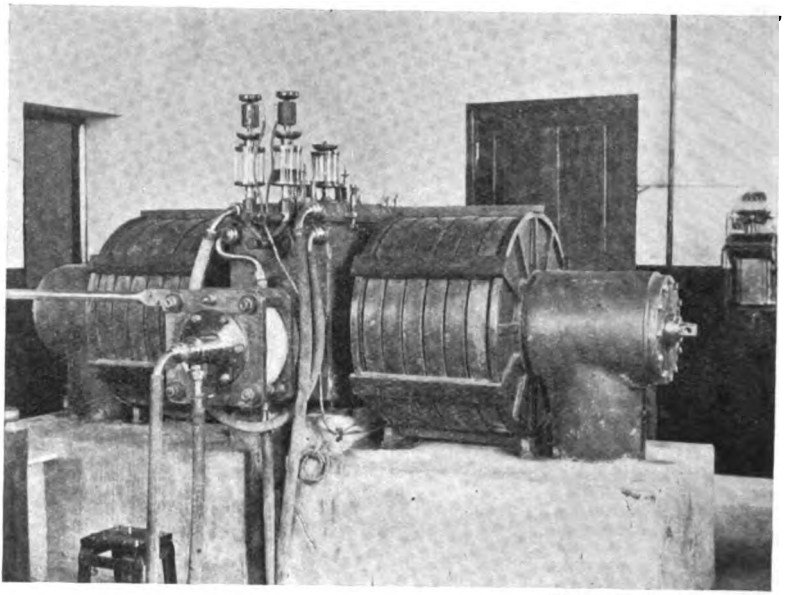

[Photo: *Sport and General.*

FIG. 11.—One of the 250 kW Elwell-Poulsen Arc Generators.

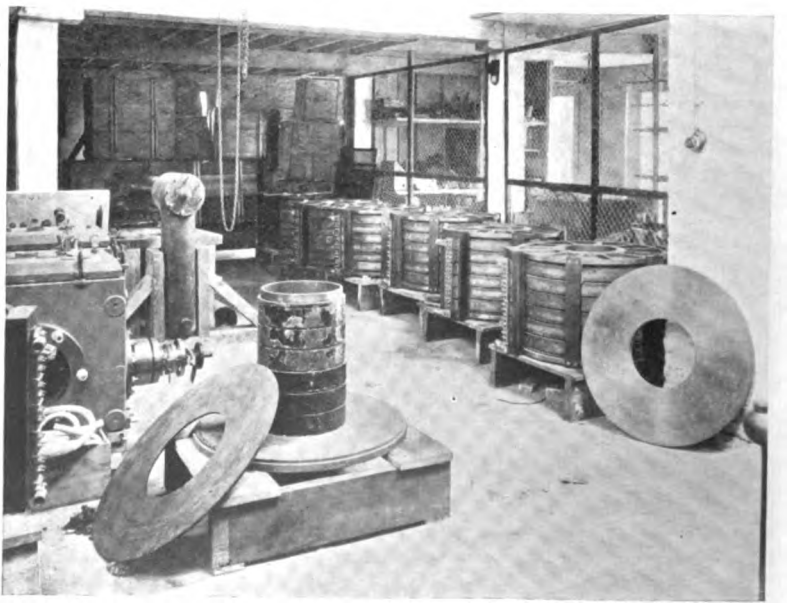

FIG. 12.—Component Parts of one of the 250 kW Arcs during manufacture at works of Messrs. C. F. Elwell, Ltd.

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the picture and the iron magnetic circuit in the centre background. The yoke of the magnetic circuit of the arc is mounted in a concrete base as may be seen in Fig. 10. Both the magnet windings of each arc can be excited by the arc supply current, and this is the arrangement used for signalling at the normal wavelength.

[Photo: *Sport and General.*

FIG. 13.—Inspection of one of the Arc Anodes.

Suitable switchgear is, however, provided to enable one of the windings to be excited from a separate 16 volt generator (which can supply currents up to 500 amps) when special wavelengths are required. The hydrogenous atmosphere for the arc is produced by dropping alcohol into the arc chamber from sight feed lubricators mounted on the top. These and the pipes leading cooling water to the cathode and to the arc chamber can also be seen in Fig. 10. The size of the arc electrodes can be judged from Figs. 13 and 14 which were taken after the opening ceremony. The cathode holder for one of the arcs is shown in Fig. 15.

[Photo: *Sport and General.*

FIG. 14.—Inspection of one of the Arc Cathodes.

The supply circuit to the arcs is taken through large choke coils which serve to maintain the arc current steady. These choke coils are shown in Fig. 16 and their position when installed in the basement of the station in Fig. 17. The striking of the arc and the necessary adjustments of the apparatus are carried out by an arc attendant, who has on a control desk in front of him (Fig. 18) instruments indicating the conditions of the arc and auxiliary apparatus. This control desk serves to operate contactors fitted in the room below the arcs which perform all the switching operations in the 1,000 volt circuits. These contactors are operated from the 220 volt circuits.

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Signalling is effected by means of a special key, shown in Fig. 19, which has been developed after extended experiments on high power. It is operated by a Creed pneumatic engine, controlled by a Carpenter relay. It is arranged to short circuit coils coupled to the keying inductance joined in the aerial circuit. The spirals of copper strip which are short-circuited by the key are arranged on either side of the keying inductance circuit as shown in Fig. 20. The arrangement of this part of the circuit is indicated in Fig. 21. A compressed air supply is fed to the contacts of the signalling key for extinguishing the arcs when the circuit is interrupted. The air compressors and the water circulation pumps are automatically started by contacts on the arc controller. The adjustment of the wavelength radiated by the aerial is made by a separate aerial tuning inductance (Fig. 22), which is constructed of stranded cable each wire of which is insulated to reduce the eddy current losses. A portion of this coil is constructed of bare copper tube for fine adjustment of the wavelength.

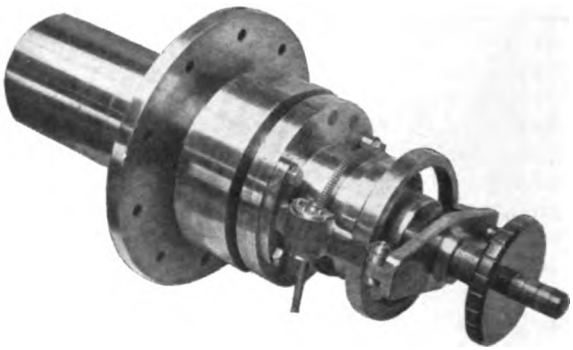

FIG. 15.—Cathode Holder for 250 kW Arc.

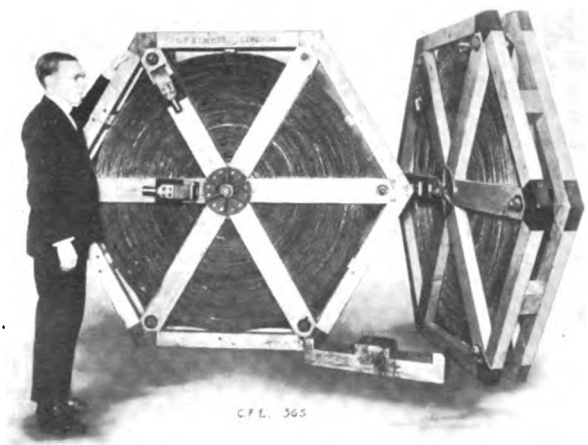

FIG. 16.—Choke Coils for 250 kW Arc.

The aerial insulators are of the porcelain rod type (Fig. 23) to which reference has already been made in these columns* and the lead-in insulator is arranged in the centre of a glass panel (Fig. 24). The earth system is buried at a depth of about 9 inches below the surface of the ground and the connections from the arc cathodes

* RADIO REVIEW, 2, pp. 197—199, April, 1921.

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to these earth wires are made by broad copper strips which pass down the outside wall of the buildings to just below the ground level where they join a similar strip running right round the building close to the walls. The radiating earth wires are soldered to this latter strip. The arc and inductance rooms are screened by means of a zinc plate which completely covers the floor area and is joined to the main earth system to prevent the induc-

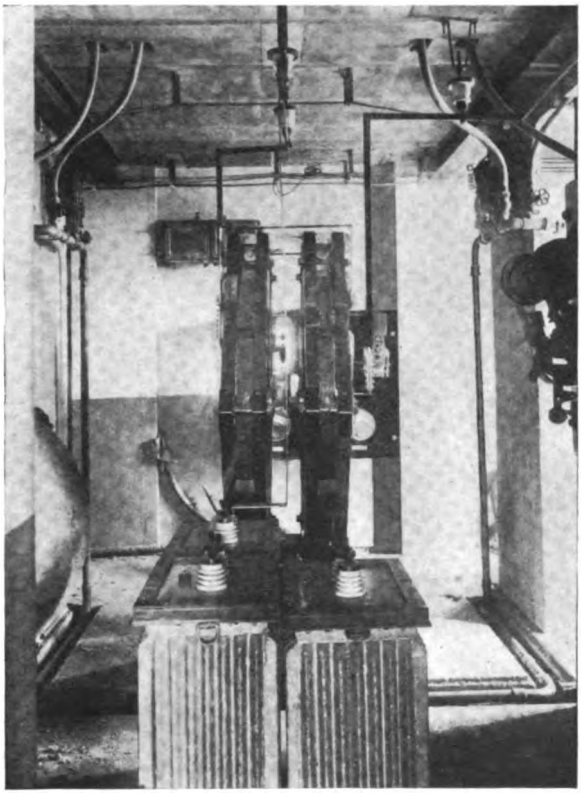

Fig. 17.—View in Basement of Leafield Station Wireless Building, showing Choke Coils in position.

tion of high frequency currents in the apparatus in the ground floor rooms below.

A separate aerial supported on 75 foot poles is temporarily used for reception at Leafield but it is proposed at a later date to build a separate receiving station near Banbury (see Fig. 1) so as to enable duplex working to be carried on.

At the conclusion of the tour of inspection of the buildings and equipment

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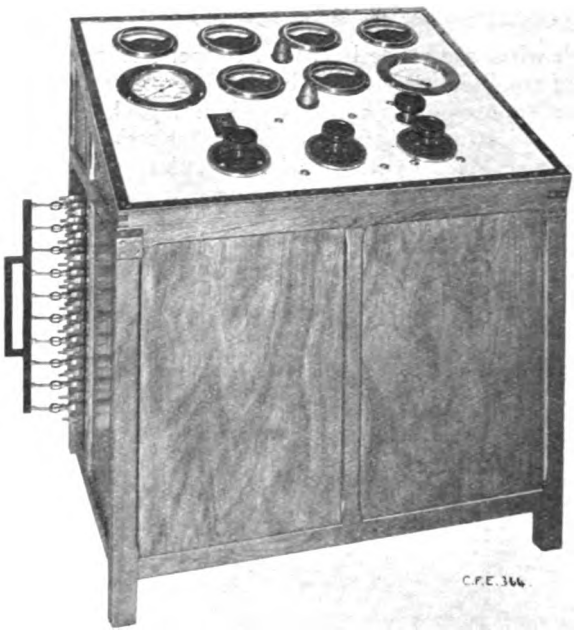

FIG. 18.—The Control Desk for one of the Arcs.

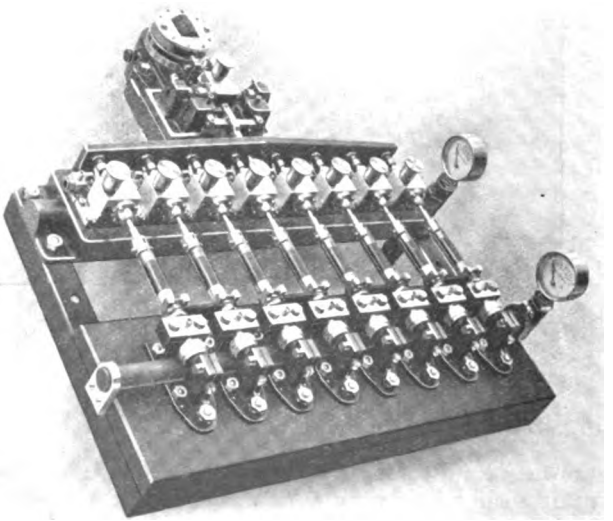

FIG. 19.—Signalling Key.

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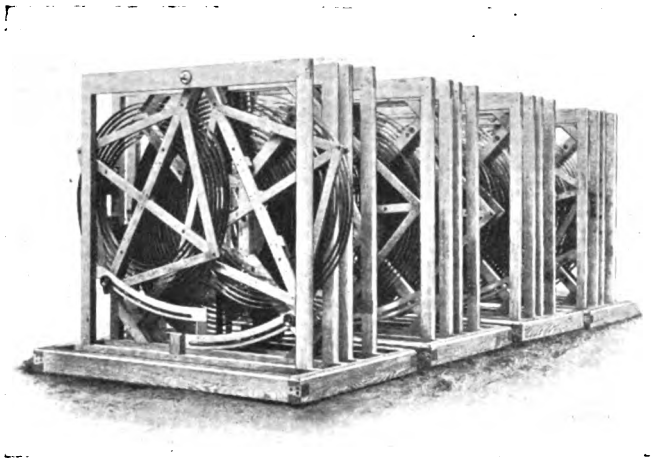

FIG. 20.—Keying Inductances in Aerial Circuit.

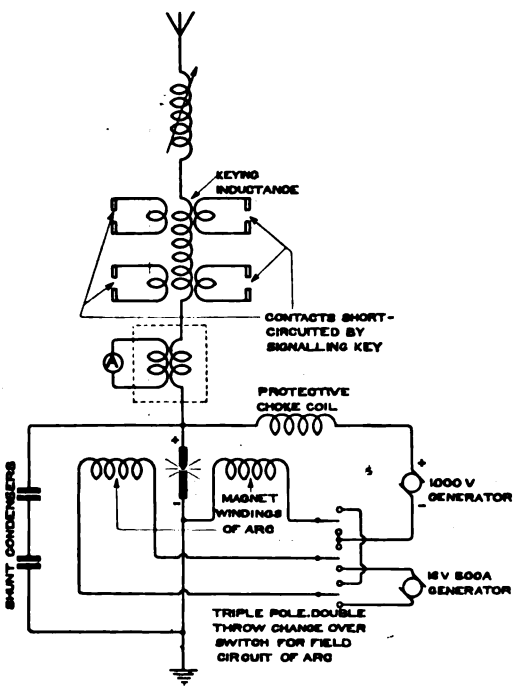

FIG. 21.

the Postmaster-General addressed a short speech to the company present in which he stated that—

it was felt that such an historic occasion should be marked by some public ceremony. He thought the Post Office suffered from too much modesty, and unless attention was occasionally called to some of its developments the public were apt to regard it as a slow and dead-alive body. Those who had visited that undertaking had had a real tonic experience, and what particularly appealed to him was the fact that nearly all the principal work was the result of British production and inventiveness. That surely should act as a tonic in these times, when they were so much given to self-depreciation. The Elwell arc transmitting equipment, which was assembled at the firm's works at Peckham, was one of the most important inventions in connection with wireless telegraphy or telephony that the world had seen, and it ought to put to shame the Jeremiahs who seemed to take a pride in deprecating British in-

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ventiveness. It was a source of gratification to him to see present on that occasion Admiral Sir Henry Jackson, who was associated with Mr. Marconi in his early experiments. He was then a captain in the Navy, and it was primarily due to Sir Henry's enthusiasm that the Navy was predominant in the matter of wireless equipment at the outbreak of war. It was difficult to believe that wireless telegraphy was only invented in 1896, when Mr. Marconi, then a young man of twenty-two, visited England and took out the first wireless patent. Mr. Marconi's first experiments were carried out in conjunction with the Post Office engineering staff under the direction of Sir William Preece, who was then engineer-in-chief, and

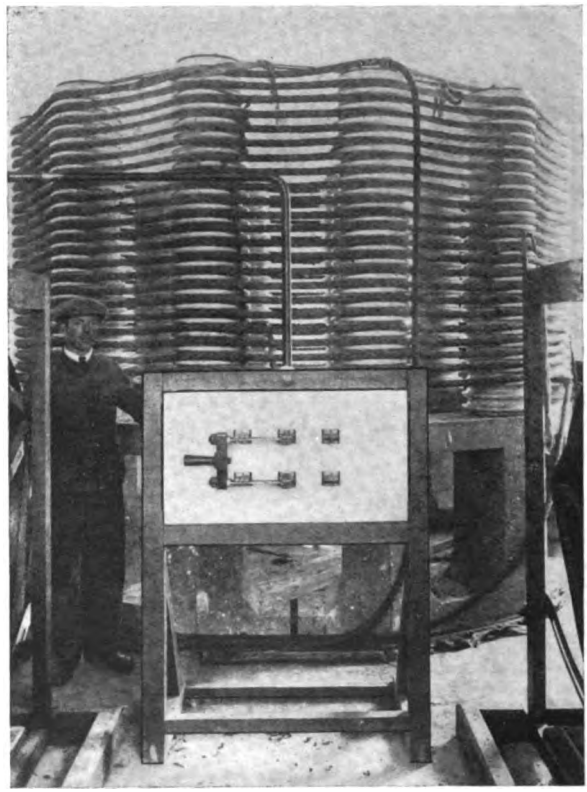

FIG. 22.—The Aerial Tuning Inductance.

Mr. Marconi has always frankly recognised the assistance he received from the department in those early days.

Having passed under review the various developments that had been made in the wireless service under the Post Office Department, Mr. Kellaway said that as regards wireless telephony the work was at present only in an experimental stage, but special attention was being paid to the development of this art, and especially to the efficient combination of wireless with wire telephony, so as to admit of speech between ordinary exchange subscribers, over the exchange and trunk lines, with ships at sea, with aircraft in flight, or with any overseas places with which wireless telephony may ultimately be possible. "I was present," he added, "at some of the Imperial Conferences, at which great interest was taken in wireless communication. It is a very fascinating prospect, and when our ambitions are realised we shall practically have

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destroyed space. If Mr. Hughes in Melbourne can take off his receiver and talk to Mr. Lloyd George in Downing Street, the amount of gratification it will give to those two statesmen is, I am sure, practically unlimited." (Laughter.) Leafield is the first station of the Imperial wireless chain, and is designed to communicate with the corresponding station at Abu Zabal, near Cairo. These two stations will form the first pair of a series of four stations. The third station will be in East Africa, and the fourth in South Africa. In accordance with the proposals of the Imperial Wireless Telegraphy Committee, which sat last year under the chairmanship of Sir Henry Norman, another pair of stations will be erected in England and Egypt, and these will be continued to India, Singapore, Australia, and Hong Kong. They are being planned by a commission of experts, consisting of Professor Eccles, Mr. L. B. Turner, of Cambridge, and Mr. E. H. Shaughnessy, of the Post Office, who is mainly responsible for the design of the present station.

"I am impressed with the fact that in many ways this is an historic occasion. This undertaking is going to do a great deal to bind closer together the various parts of the Empire and to break down barriers which distance and time would otherwise create. This is the first and to some extent a modest effort, but although modest it is going to justify the work the Post Office engineers have put into it." (Cheers.)

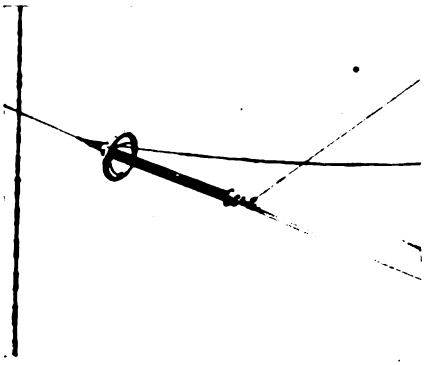

FIG. 23.—One of the Aerial Insulators.

FIG. 24.—Aerial Lead-in.

The corresponding station at Abu Zabal was being proceeded with rapidly, and it was expected to be ready in three months' time. That station and the Abu Zabal station would then carry on a service between England and Egypt, and the Abu Zabal station would also be used for communication with Mesopotamia, and perhaps for broadcasting news to India; it would also, pending the completion of the rest of the stations of the system, exchange traffic with the Eastern Telegraph Company's cables beyond Egypt. In view of the pressure on the cables between this country and Egypt, the service to be provided by this pair of stations could not but be useful from a commercial point of view. The rate by wireless between this country and Egypt would be 9*d*., as compared with the present charge of 1*s*., and there would be corresponding reductions for deferred and other telegrams, but, of course, the main importance of the stations would consist in their being the first links in the chain to South Africa. The Government had been criticised by persons who spoke with limited knowledge—that most dangerous equipment for controversy—for going on with a 2,000-mile link scheme instead of proceeding to set up stations of tremendously wider power. Those grandiose people always broke down immediately they came to questions of expense. In increasing power in wireless they increased the expense altogether out of proportion to the increase in power. Those people were not satisfied with a practical system which obtained the results that were desired. It seemed to him that three things were necessary in any system of communications—reliability was the first essential, the second was cheapness, and the third was speed. By adopting the system of links of 2,000 miles they hoped to provide the most reliable, the most economical, and taking the whole year through the speediest system. It was an achievement of which the British Post Office had a right to be proud. (Cheers.) [4090]

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Optimum Wavelength and Atmospherics.*

By L. B. TURNER, M.A., M.I.E.E.

1. Symbols Employed.

λ = Wavelength, km.

n = Frequency, periods per sec.

$p = 2\pi n$.

x = Distance between transmitter and receiver, km.

h_s = Height of transmitting aerial, km.

I_s = Current in transmitting aerial (peak value), A.

F, H = Electric and magnetic field strengths, E-M. C.G.S. units.

ρ = Damping index $\frac{R}{2L}$ of receiving antenna, Ω/H.

δ = Decrement $\frac{R}{2nL}$ of receiving antenna.

$F_a \cdot \epsilon^{-rt}$ = Electric field at receiver due to an atmospheric.

P = Power in receiving antenna derived from signal, W.

q = M. Abraham's " Störungsfreiheit " ratio

= (Energy from signal) ÷ (energy from atmospheric).

f = " Immunity fraction "

$= \frac{q}{q_{max.}}$

c = Velocity of propagation = 3×10^{10} cm/sec.

Where a dashed symbol, *e.g.* q', is also used, it refers to aerial reception, the undashed symbol referring to loop reception.

2. Introductory.

Since Hertz first demonstrated the transference of power from one electrical circuit to another by radiation across the intervening medium, engineers, in applying the phenomenon to telegraphic purposes, have proceeded steadily from short to longer wavelengths. Hertz produced waves of some 2 metres; in Marconi's early experiments the wavelength was of the order of 20 metres, which had grown to some 200 metres when the first practically useful wireless telegraphy had been achieved; by the early days of transatlantic signalling the advance had been carried to 2,000 metres; and to-day the Croix d'Hins station is transmitting regularly at over 20,000 metres; from 1887 to 1921 an increase in wavelength of 10,000 times. Whereas Hertz's achievement was the production of electric waves of frequencies invisibly low, difficulties are

* Received June 30th, 1921.

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experienced to-day because the frequencies employed tend to be—are—no longer even inaudibly high.

There are, of course, many factors which together control the choice of wavelength, and amongst them three have been very prominent in requiring increased length—(*a*) With rising antenna power, larger antennæ have been required to restrict corona loss; (*b*) more powerful high-frequency generators, particularly of the arc and alternator types, have necessitated lower frequencies of oscillation; and (*c*) the spatial attenuation of field intensity over the surface of the earth has called for greater wavelengths over greater ranges. It is the last consideration which has been generally associated with the term "optimum wavelength."

If the earth were flat and well conducting, and the atmosphere an unlimited perfect dielectric, the field at a distance x from a non-directive transmitting aerial would be

$$F = c \cdot H = c \cdot \frac{2\pi}{10^6} \cdot h_s I_s \cdot \frac{1}{\lambda x} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and as long as we could take $h_s I_s$ as sensibly independent of the choice of λ, the received intensity at any distance would increase indefinitely as the wavelength were reduced. Over earth's surface, however, the intensity is found to fall off more rapidly than this; and a truer formula is

$$F = c \cdot H = c \cdot \frac{2\pi}{10^6} \cdot h_s I_s \cdot \frac{1}{\lambda x} \cdot \epsilon^{-\beta} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where β is a function of λ and x.

With the same assumption that $h_s I_s$ is unaffected by choice of λ, there is now for each value of x a value λ_o of the wavelength which makes the field strength a maximum:

$$\lambda = \lambda_o, \text{ when } \frac{d}{d\lambda}\left[\frac{\epsilon^{-\beta}}{\lambda}\right] = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

According to L. W. Austin's and other measurements

$$\beta = \frac{0{\cdot}0015x}{\lambda^{\frac{1}{2}}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

which leads to the well known optimum wavelength formula

$$\lambda_o = 5{\cdot}6 \times 10^{-7}x^2 = (0{\cdot}00075x)^2 \quad . \quad . \quad . \quad . \quad . \quad (5)$$

According to L. F. Fuller's suggestion, recently supported by G. Vallauri's measurements of Annapolis' signals at Leghorn,

$$\beta = \frac{0{\cdot}0045x}{\lambda^{1{\cdot}4}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

which leads to the formula

$$\lambda_o = 0{\cdot}027x^{0{\cdot}71} = (0{\cdot}0063x)^{0{\cdot}71} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

These "optimum wavelengths" λ_o are calculated for four ranges in Table I.

It is generally taken that the choice of wavelength for any given service should be made in this way, subject, of course, to the wavelength so selected not proving impracticable from some other consideration such as those named

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at (*a*) and (*b*) above. Of the two attenuations mentioned, the Austin-Cohen factor is the more firmly established, at least for moderate wavelengths and ranges; for it has been widely checked as roughly true for normal daylight signalling with wavelengths up to 4 km and ranges up to 4,000 km. On this basis we should arrive, for example, at a wavelength of about 5½ km for a Clifden—Glace Bay Service. This is not very far from the wavelength actually used. Others of the transatlantic transmitters, *e.g.* Croix d'Hins and New Brunswick, employ much longer waves than the above calculations would indicate, and may serve to illustrate the operation of the other factors, such as the difficulty of working a very large arc or alternator except at very great wavelengths.

TABLE I.

Range x km	λ_0 km	
	Austin	Fuller
3,000	5·1	8·0
4,000	9·1	9·9
5,000	14·1	11·7
10,000	56	19

The assumption,* explicit or implicit, that wavelength should be chosen to give maximum received field or antenna current can not, however, be accepted. The absolute strength of received field is nowadays of secondary importance, for amplifiers enable us to deal with almost any strength, however small. The problem of problems in wireless telegraphy to-day is not how to make the signal perceptible, but how to make the signal more perceptible than the atmospherics. It is the ratio (signal strength) ÷ (atmospherics strength) which is of primary importance.

Since the fields are not perceived directly, but by the currents they cause in the antenna, the relevant ratio is not that between field strengths of signal and atmospheric, but between signal and atmospheric effects within the receiving circuits. This ratio is, indeed, proportional to the field strength ratio; but it is also a function of wavelength and form of antenna—and, of course, of arrival forms of signal and atmospheric. The purpose of the present paper is to draw attention to the very important bearing of this conception on the determination of optimum wavelength. The calculations are based upon a recent theoretical investigation by M. Abraham † of the

* Examples of this assumption are found in Professor Howe's article "The Power required for Long-Distance Transmission," RADIO REVIEW, 2, pp. 598—608, September, 1920; and in the opening paragraph of Mr. C. F. Elwell's Introductory Notes to the Discussion on "Long-Distance Wireless Transmission" at the Institution of Electrical Engineers, May 25th, 1921. (See RADIO REVIEW, 2, p. 373, July, 1921, for abstract.)

† "Die Spule im Strahlungsfelde, verglichen mit der Antenne." (*Jahrbuch der drahtlosen Telegraphie*, 14, pp. 259—269, August, 1919—RADIO REVIEW Abstract No. 72, December, 1919.)

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relative immunity from atmospheric disturbance in closed loop and open aerial forms of receiving antennæ. In the earlier part of the present paper both loops and aerials, and both Austin-Cohen and Fuller attenuations, are considered; and the bearing of wavelength upon speed of signalling is also touched upon. Subsequently the investigation is restricted to the open aerial and the Austin-Cohen attenuation.

3. Signal versus Atmospheric.

Abraham has calculated (*loc. cit.*) for a C.W. signal sustained during long time T the ratio—which he calls the "Störungsfreiheit," *i.e.* immunity from disturbance—

$$q = \frac{\text{energy from signal}}{\text{energy from an atmospheric}}$$

absorbed by loop and aerial forms of receiving antenna, on the following assumptions:—

Arrival form of field due to atmospheric is a suddenly rising aperiodic pulse $F_a\epsilon^{-rt}$;

Low antenna decrement, *i.e.* $\rho << p$;

Atmospheric damping is much greater than antenna damping, *i.e.* $r >> \rho$. These Störungsfreiheit ratios, for loop and aerial respectively, are:—

$$q = \left(\frac{F}{F_a}\right)^2 \cdot \frac{1}{2\rho} \cdot \frac{p^4(p^2 + r^2)}{r^4} \cdot T \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$q' = \left(\frac{F}{F_a}\right)^2 \cdot \frac{1}{2\rho'} \cdot \frac{p^2(p^2 + r^2)}{r^2} \cdot T \quad . \quad . \quad . \quad . \quad . \quad (8a)$$

The quality of the receiving antenna with respect to disturbance is thus a known function of ρ, p and r.

It is to be noted in passing that these expressions indicate that disturbance from atmospherics is indefinitely reduced in either form of antenna, and whatever the value of r, by reducing the decrement of the antenna or/and reducing the wavelength.

When, as Abraham considers is usually the case,*

$$r^2 << p^2$$

we have

$$q = \left(\frac{F}{F_a}\right)^2 \cdot \frac{1}{2\rho} \cdot \frac{p^6}{r^4} \cdot T \propto \frac{F^2}{\delta} \cdot \frac{1}{\lambda^5} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

$$q' = \left(\frac{F}{F_a}\right)^2 \cdot \frac{1}{2\rho'} \cdot \frac{p^4}{r^2} \cdot T \propto \frac{F^2}{\delta'} \cdot \frac{1}{\lambda^3} \quad . \quad . \quad . \quad . \quad . \quad (9a)$$

4. Optimum Condition.

Provided that the signal power received does not turn out to be too extremely small to be conveniently dealt with by modern amplifiers, the best wavelength is that which makes the "Störungsfreiheit" ratio q a maximum. We will investigate this condition for the above form of atmospheric, viz.

* Lightning fields are known to die away in $\frac{1}{10000}$ to $\frac{1}{100000}$ sec, corresponding to (say) $r = 5{,}000$ to $50{,}000$, and are almost certainly non-oscillatory.

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$r^2 << p^2$, on the assumption that δ does not depend on λ. (Actually δ is completely under control by retroactive triode devices.) Putting for F the function of λ and x of equation (2), the above expressions (9) and (9a) become

$$q \propto \frac{1}{\delta} \cdot \frac{\epsilon^{-2\beta}}{\lambda^7 x^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

$$q' \propto \frac{1}{\delta'} \cdot \frac{\epsilon^{-2\beta}}{\lambda^5 x^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10a)$$

We have to find the values of λ which make these expressions a maximum.

Whether for β we take expression (4) or (6), both of the expressions (10) and (10a) are of the form—

$$q \text{ or } q' \propto \frac{\epsilon^{-2ux\lambda^{-v}}}{\lambda^w x^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

where u, v are numbers depending on whether the Austin-Cohen (4) or Fuller (6) attenuation is taken, and w is a number depending on whether the antenna is a loop or aerial ((10) or (10a)). Differentiating (11) with respect to λ, and equating to zero, we find that the maximum occurs when

$$\lambda = \left(\frac{w}{2uvx}\right)^{-\frac{1}{v}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

This is the optimum wavelength we seek.

Putting in the appropriate values of u, v and w we find from (12)

Austin-Cohen

$$\lambda_{opt.} = (0{\cdot}00021x)^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

$$\lambda'_{opt.} = (0{\cdot}00030x)^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13a)$$

Fuller

$$\lambda_{opt.} = (0{\cdot}0018x)^{0.71} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

$$\lambda'_{opt.} = (0{\cdot}0025x)^{0.71} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14a)$$

These optimum wavelengths are calculated in Table II. for the four ranges 3,000, 4,000, 5,000 and 10,000 km.

TABLE II.

$r^2 << p^2$.

Range x in km	Optimum wavelength in km			
	Austin-Cohen		Fuller	
	Loop	Aerial	Loop	Aerial
3,000	0·40	0·81	3·3	4·2
4,000	0·71	1·44	4·05	5·1
5,000	1·10	2·25	4·8	6·0
10,000	4·4	9·0	7·8	9·8

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As the form of the atmospheric field is a matter of some uncertainty, in Table III. the optimum wavelengths are recalculated for the (less probable) case of very rapidly damped atmospheric, viz. for $r^2 >> p^2$.

Table III.

$r^2 >> p^2$.

Range x in km	Optimum wavelength in km			
	Austin-Cohen		Fuller	
	Loop	Aerial	Loop	Aerial
3,000	0·81	2·25	4·2	6·0
4,000	1·44	4·0	5·1	7·4
5,000	2·25	6·25	6·0	8·7
10,000	9·0	25	9·8	14·1

5. High-Speed Signalling.

In the foregoing sections it has been assumed that the transient epoch, during which the current amplitude in the receiving antenna gradually grows under the action of the E.M.F. impressed by the signal, is so short as to be a negligible portion of the whole signal epoch, the Morse dot. In high-speed, long-wave telegraphy this assumption may not be permissible. The true

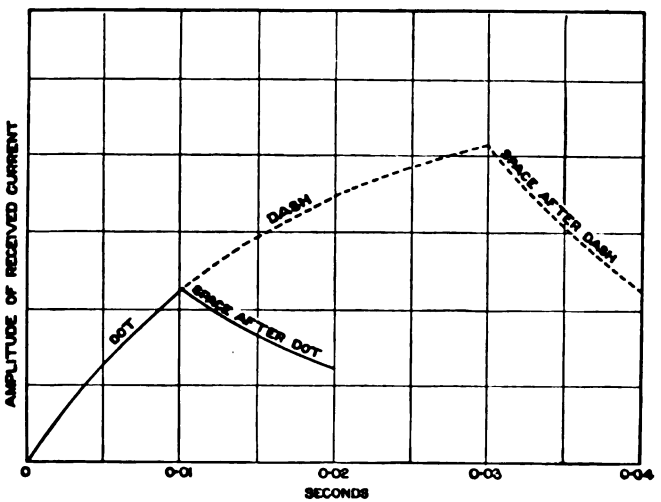

Fig. 1.—Signalling at 125 words per minute.
$\lambda = 10{,}000$ m. $\delta = 0\ 002$

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expression for the current amplitude at any time t after the beginning of the signal is

$$I\ (1 - \epsilon^{-n\delta t}).$$

We have hitherto taken $(1 - \epsilon^{-n\delta t})$ as sensibly unity throughout the Morse dot.

Writing θ for the duration of the dot, it is clear that this approximation is not permissible unless $n.\delta.\theta$ is sufficiently large—say over 3 or 4. This is illustrated in Fig. 1 for the numerical case:

$n = 30{,}000$ *p.p.s.* *i.e.*, $\lambda = 10$ km.
$\theta = 0{\cdot}01$ sec. *i.e.*, 125 words/min.
$\delta = 0{\cdot}002$. $n\delta\theta = 0{\cdot}6$.

It is manifest that ordinary methods of Morse signalling would be impossible here.

A rather elaborate examination of various numerical cases has shown that for "well-shaped" Morse signals to be given by the indicator actuated by the received antenna current, $n\delta\theta$ must not be allowed to fall below about 1·8. This limits us, in reducing δ for purposes of gaining sensitivity and freedom from atmospheric disturbance, to the value giving

$$\rho = n\delta = \frac{1{\cdot}8}{\theta}$$

In cases (high speed, long wave, low decrement) where $n\delta\theta$ would, if not prevented on this account, approach such low values as 2 and less, this has the effect of lowering somewhat further the optimum wavelength. The high-speed consideration in its bearing on optimum wavelength is not further analysed here; but it should be borne in mind that its effect, however large or small, is necessarily towards the choice of waves still shorter than the low-speed optima of Tables II. or III.

6. Limitation of the Investigation.

Henceforth in these notes the investigation is narrowed to ranges not exceeding 5,000 km, and to the Austin-Cohen attenuation factor. Whether or not the latter is generally applicable, it is known to be a fair approximation to the observed average daylight attenuations for such ranges and wavelengths as are hereafter contemplated. Further, we adhere—with ever

TABLE IV.

Range	Best wavelength	
	Loop	Aerial
3,000 km	0·40 km	0·8 km
4,000 km	0·71 km	1·4 km
5,000 km	1·10 km	2·2 km

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greater confidence as the wavelength is diminished—to our assumption that $r^2 << p^2$.

For slow speed and with Austin-Cohen attenuation, then, we extract from Table II. the values set out in Table IV. The issue is hereafter further confined to *aerial* reception. We proceed to compare conditions at the receiver when the wavelength is increased from the optimum values above calculated.

7. Received Power, and Immunity Fraction.

The maximum power receivable from the field F at wavelength λ—viz. when total antenna resistance equals twice the radiation resistance—is *

$$P'_{max.} = \frac{2{\cdot}37 \times 10^7}{c} E^2\lambda^2 \text{ E-m units}$$

$$= 2{\cdot}80 h_s^2 I_s^2 \frac{\epsilon^{-0{\cdot}0030x/\sqrt{\lambda}}}{x^2} \text{ watt} \quad . \quad . \quad . \quad . \quad . \quad (15)$$

From (10a) and (4), $q' = k \dfrac{\epsilon^{-0{\cdot}0030x/\sqrt{\lambda}}}{\lambda^5 x^2}$ where k is not a function of λ or x.

Further, we have found (13a) that $q' = \text{max.}$ when $\lambda = (0{\cdot}0030x)^2$.

Hence $$f = \frac{q'}{q'_{max.}} = 1{\cdot}1 \left(\frac{0{\cdot}3x}{1{,}000}\right)^{10} \frac{\epsilon^{-0{\cdot}0030x/\sqrt{\lambda}}}{\lambda^5}$$

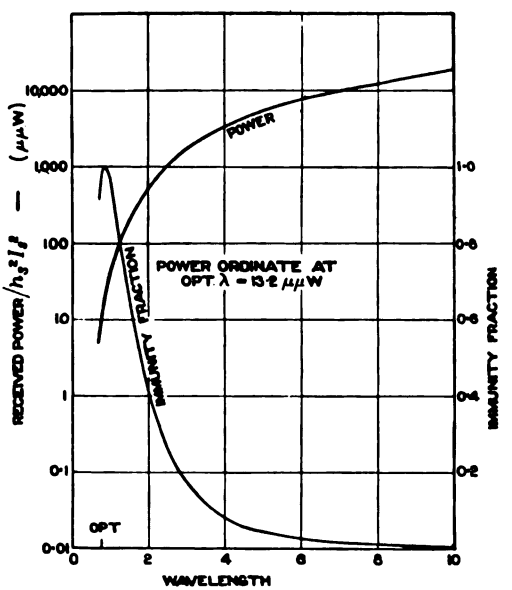

FIG. 2.—Received Power and Immunity Fraction as functions of wavelength for range 3,000 km.

The ratio f may be termed the "immunity fraction"; it measures the immunity from disturbance experienced at wavelength λ as a fraction of the immunity which would be experienced at the optimum wavelength.

The power $P'_{max.}$ and the immunity fraction $f = \dfrac{q'}{q'_{max.}}$ are plotted as functions of λ for the three ranges in the graphs, Figs. 2, 3, 4.

8. Meaning of the Graphs.

In examining the graphs the following points should be noticed:—

(*a*) The peak of the immunity fraction curve gives the optimum wavelength for

* Abraham, *loc. cit.*, p. 265.

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the range, in the sense that at that wavelength atmospheric disturbance is a minimum.

(*b*) The ordinate of the power curve is the received power in micromicrowatts for 1 square kilometre-ampere in the sending aerial. The power does not reach a maximum as wavelength is increased, because we have not chosen a fixed antenna resistance independent of the wavelength as is often done (*e.g.* Austin's 25 ohms). Our assumption of optimum antenna resistance (viz. twice the radiation resistance) seems a more practical basis when dealing with open aerials and short waves; for then, if we are concerned

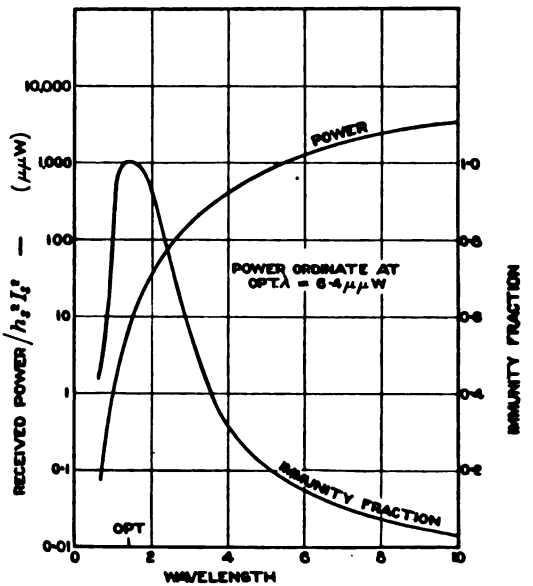

FIG. 3.—Received Power and Immunity Fraction as function of wavelength for range 4,000 km.

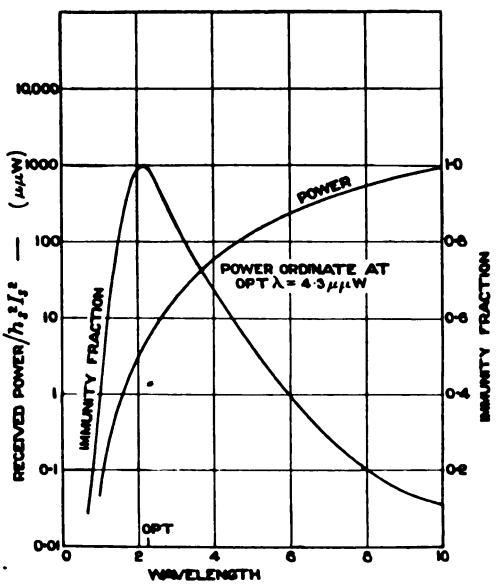

FIG. 4.—Received Power and Immunity Fraction as function of wavelength for range 5,000 km.

to increase the received power, it is feasible to obtain high radiation resistance.

(*c*) In each of the three ranges, doubling the wavelength from the optimum value nearly doubles the atmospheric interference. The power received from the signal is increased about 20 times, but the power from atmospherics is increased nearly 40 times.

(*d*) The graphs do not show how the value of the "Störungsfreiheit" ratio q' decreases as range is increased. This is given, however, for assumed constant decrement, by the formula (10a).

$$q' \propto \frac{\epsilon^{-2\beta}}{\lambda^5 x^2}$$

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With the Austin-Cohen attenuation and the optimum wavelength, this becomes

$$q'_{\max.} \propto \frac{1}{x^{12}}.$$

Hence if minimum disturbance is taken as unity at 3,000 km

at 4,000 km it is 31,

at 5,000 km it is 460.

It is to be remembered that throughout we are comparing powers, not currents or E.M.F's.

9. Numerical Case.

As a numerical example of choice of wavelength, let us consider a 4,000 km range, with sending aerial 0·08 km high, 141 amps (R.M.S.) in the aerial, and alternative wavelengths of 8·2 km and the optimum, 1·4 km, shown in Fig. 3. Here $h_s I_s = 16$ km-A.

From (2) and (4) the received fields are:

$$\text{at } \lambda = 8{\cdot}2. \qquad H = 3{\cdot}7 \times 10^{10}$$

$$\text{at } \lambda = 1{\cdot}4. \qquad H = 1{\cdot}1 \times 10^{10}.$$

From graphs in Fig. 3,

$$\text{at } \lambda = 8{\cdot}2 \begin{cases} \text{Power} = 2{,}600 \times 256\ \mu\mu\text{W} = 0{\cdot}67\ \mu\text{W}. \\ \text{Immunity fraction} = 0{\cdot}07. \end{cases}$$

$$\text{at } \lambda = 1{\cdot}4 \begin{cases} \text{Power} = 6{\cdot}4 \times 256\ \mu\mu\text{W} = 0{\cdot}016\ \mu\text{W}. \\ \text{Immunity fraction} = 1. \end{cases}$$

Without retroactive triode devices, the received power of 0·67 μW at $\lambda = 8{\cdot}2$ km could not in practice be obtained; for masts of colossal height would be necessary to give a radiation resistance approaching half the total resistance. Taking the height of receiving aerial as 0·08 km, its radiation resistance would be 0·15 ohm. If it were impossible to reduce the total resistance below (say) 1·3 ohms, the received power would be $0{\cdot}67 \times \frac{0{\cdot}30}{1{\cdot}3} = 0{\cdot}16\,\mu$W (and most of this would not reach the detector). On the short wave, however, the radiation resistance would be 5 ohms, and the calculated power could be easily obtained (and most of it be delivered to the detector).

Thus the reduction of wavelength from 8·2 to 1·4 km may be taken as dividing the received power by (say) about 10, while reducing atmospheric interference some $\frac{1}{0{\cdot}07} = 14$ times.

It appears, therefore, that the shorter wavelength would give much better service, as far as atmospheric troubles are concerned. Before such a wavelength could be adopted, it would be necessary to consider the other factors referred to in section **2**. Continuing with our numerical example, assuming

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that we have a triode or other oscillator competent to produce the assumed antenna current of 141 amperes at the frequency corresponding with 1·4 km wavelength, would the received power be not impracticably small ? and could the antenna voltage at the transmitter be kept sufficiently low ?

It is not easy to quote a figure for the smallest practicable received power. G. W. O. Howe,* for the purpose of his transmission calculations, takes $H = 1{\cdot}7 \times 10^{-9}$ as adequate for good signals, apparently without regard to wavelength. It is doubtful whether the disregard of wavelength is justifiable; and in any case this figure is apparently based on Austin's experiments in 1910 using a crystal detector. G. Vallauri † found $H = 2{\cdot}6 \times 10^{-9}$ adequate even when receiving a wave of 17,300 m on a loop (without retroactive reduction of its resistance) of area only about $(0{\cdot}037 \text{ km})^2$. J. H. Dellinger ‡ reports cases of loud signals, without heterodyne, with received antenna powers down to 25 $\mu\mu$W. With heterodyne it would doubtless be feasible to work with much less than 1 $\mu\mu$W. Hence it appears that in our numerical example, the received power is quite adequate, and need not impose restriction on choice of wavelength.

We may then consider corona loss at the transmitter. To limit aerial potential to (say) 50 kV, the capacity must be not less than 0·0031 μF. This capacity (roughly) would be given by a cage aerial 200 m long and 6 m in diam.—a not unpractical form of aerial. The aerial would radiate 100 kW.

10. Conclusion.

Theoretical considerations, based on such experimental facts as are available, indicate that for ranges such as 4,000 km much shorter waves should be adopted than are usually contemplated, provided the requisite power can be developed at such wavelengths. The calculations are based on assumptions as to the arrival form of the more troublesome atmospherics and as to the relation between attenuation and wavelength, which assumptions are open to a good deal of doubt. The theoretical conclusions arrived at are therefore much in need of direct experimental support. As far as they go, the recently published § German experiences at Togoland just before and after the outbreak of war are an interesting confirmation of the general contention that relative freedom from atmospherics, and not strength of desired signals, must be the criterion in choosing wavelengths. The distance between Nauen and Togo is over 5,000 km, so that according to Table I. the wavelength for strongest signals would be over 12 or 14 km. Many trials with different wavelengths were made, and led to the selection of 4·5 km, on which wave considerable traffic was carried out. "No text could be received with the wavelength of 9,400 m, although the sound intensities were good, because the disturbances were far greater than with smaller wavelengths." **[3593]**

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* RADIO REVIEW, 1, p. 599, September, 1920.

† *Proceedings of the Institute of Radio Engineers*, 8, p. 294, August, 1920.

‡ *Scientific Papers of the Bureau of Standards*, No. 354, p. 479, 1919.

§ See R. Roscher. "Nauen and Togoland: A Tragedy of Radio-Telegraphic Development." RADIO REVIEW, 2, pp. 68—75, February, and pp. 250—261, May, 1921. (Abstracted from *Archiv für Post und Telegraphie.*)

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The Wireless Service for Press Messages from Geneva.

In order to facilitate the transmission of press despatches from Geneva during the second assembly of the League of Nations a special wireless service has been installed by Marconi's Wireless Telegraph Co., Ltd., to give direct communication from Geneva to London and to Denmark, Norway, Sweden and Spain. A standard 6 kW Marconi valve transmitter has been installed at Berne (Mönchenbuchsee) and is controlled and automatically operated at high speed from Geneva. The controls and transmitting key are fitted in a room at the Hotel Victoria adjoining the Reformation Hall, in which the meetings of the League are held. The equipment is of a somewhat temporary nature and use has been made of the two steel lattice towers in course of erection by the Marconi Company for the Swiss Government.

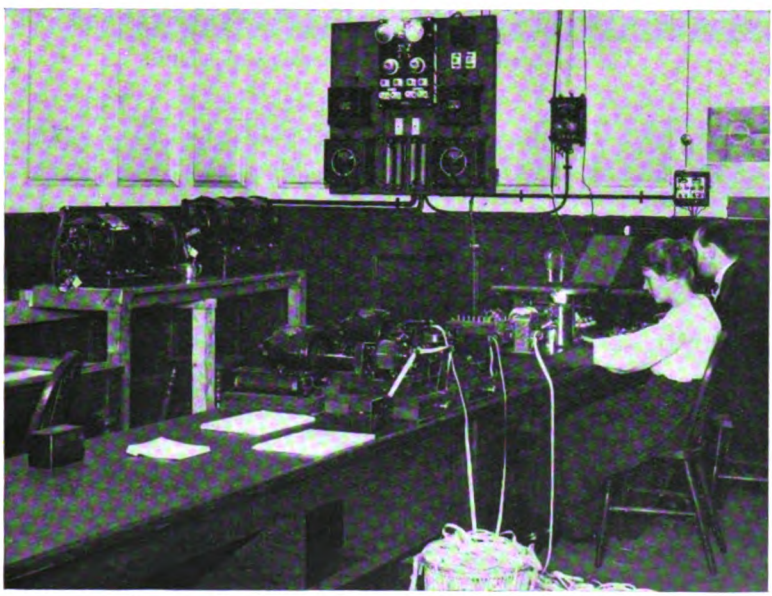

Fig. 1.—The Creed Printing and Recording Apparatus.

These towers when completed will be 300 feet high but at the present time only 200 feet is being used for supporting the transmitting aerial. Power is obtained from a 13 kW Austin petrol-driven generating set. The transmitting wavelength is 3,400 metres.

Since the bulk of the traffic is outgoing from Geneva high speed transmitting equipment has been installed but only an ordinary pattern of receiving apparatus. The receiver, using a D.F. aerial, has been set up at Arare about five miles outside Geneva. This receiving station is in telephonic communication with Geneva.

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FIG. 2.—Another view of the Recording Apparatus.

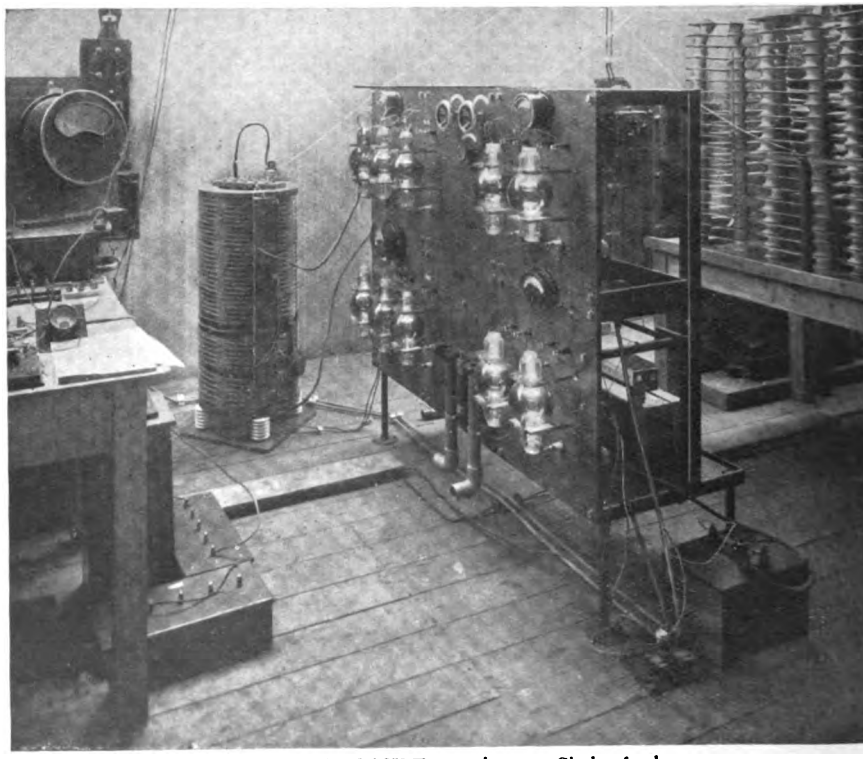

FIG. 3.—The 6 kW Transmitter at Chelmsford

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The reception of the signals in England takes place at Witham in Essex, the receiving station normally employed for the wireless service to Paris being utilised. A D.F. aerial 100 feet high with a span of 200 feet is employed for reception. A 7-valve amplifying receiver is employed in conjunction with note magnifying valves and special circuits for relaying the incoming signals on to the landlines whence they are relayed directly through to Marconi House, London. The latter place is thus in direct communication with Geneva. The final reception of the messages takes place on an "undulator" and a Creed receiver and printer. Two views of the receiving and printing apparatus as installed in Marconi House are given in Figs. 1 and 2. A key has also been installed in Marconi House which operates, *via* the landlines, a 6 kW valve transmitter at Chelmsford (Fig. 3). This is used for sending acknowledgments and service instructions back to the Geneva receiving station. The aerial at Chelmsford consists of two wires 500 feet in length suspended from a 210 feet tubular steel mast of the "Gray" type. These wires are carried out to two 50-foot poles and thence back to the transmitting house. A wavelength of 3,000 metres is employed for this purpose. **[4026]**

Modern Methods of Valve Manufacture.

The needs of the Services during the war have led not only to important developments in the design of thermionic valves, but to equally important improvements in the methods used for their manufacture and testing. The manufacture of valves in large quantities, on a "mass production" basis, necessitates the use of different methods than are required for the construction of small quantities of experimental tubes. The most important requirement necessarily is standardisation of all the component parts so that the finished products will be interchangeable both electrically and mechanically and will conform to a given specification.

An inspection of the works of the Mullard Radio Valve Co., Ltd., at Hammersmith reveals some of the methods that may be employed in the manufacture of valves for modern requirements. Each valve passes through a series of separate processes, the operatives at each stage performing in the main one operation only. The various separate parts of the valve are thus built up from the raw materials, and finally assembled to make the finished product.

Following the manufacture of a small valve right through the works we may note the following details:

Firstly, the preparation of the leading-in wires.

Pieces of copper and nickel wire are cut off to the correct length using a suitable gauge, and are then welded to a platinum connecting wire in a small blowpipe flame, so that the nickel wire serves for supporting the electrodes inside the glass stem, while the copper is used for the external connections to the valve cap.

The valve electrodes are prepared from sheet nickel and nickel wire respectively, the former being stamped out to the correct size and welded to one of the above-mentioned nickel supporting wires by means of a small

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electric welder. It is then shaped round an appropriate gauge to give it the desired cylindrical shape. The latter, the grid, is built up of molybdenum wire coiled up into a spiral and similarly attached to its supporting wires.

A special machine is employed for cutting off uniform lengths of glass tubing to form sealing stems for the valves. These lengths of glass are then fed by hand into a flanging machine consisting of two chucks driven round by an electric motor and provided with a foot pedal release so that a piece of glass tube can be gripped in one of the chucks without stopping its rotation. Meanwhile the second or upper chuck is rotating another piece of tubing in the blowpipe flame, so that by the time a finished flanged tube has been ejected from the lower chuck and a new piece of tubing inserted in its place, the tubing in the upper chuck is hot enough for flanging. The four supporting wires for the electrodes are sealed into one end of this flanged tube so as to form the stem of the valve.

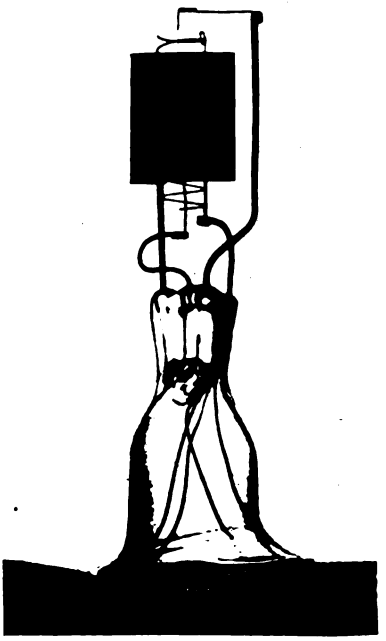

FIG. 1.—Electrodes mounted on Stem.

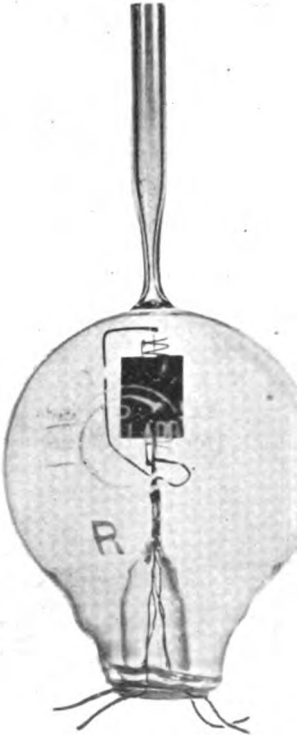

FIG. 2.—Electrodes mounted in Bulb before Exhaustion and Finishing.

After the mounting of the grid and anode of the valve on to their supporting wires the filament is threaded down the centre of the grid and secured to the terminal wires by pinching. The finished glass stem with the electrodes and filament mounted in place is shown in Fig. 1. Tension on the filament is maintained by means of a small flat spring to which its

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upper end is attached as may be seen in the illustration. The next process consists in the preparation of the bulb in which the component parts of the valve are to be inserted. In valves of the R type this is usually nearly spherical in shape but for the K and D type valves a more elongated cylindrical bulb is used. A spherical type of bulb with stem and electrodes sealed into place is shown in Fig. 2 and the completed bulb after sealing off but before capping, in Fig. 3. During the exhaustion of the valve and before its sealing off it is subjected to electrical tests both to drive out occluded gases from the metal electrodes and to indicate the state of the vacuum. For this purpose high voltages are applied to the valves so as to heat up the electrodes by electronic bombardment and thus to drive out the gases. When the blue glow has disappeared a satisfactory state of vacuum is indicated and the valve may be sealed off from the pumps.

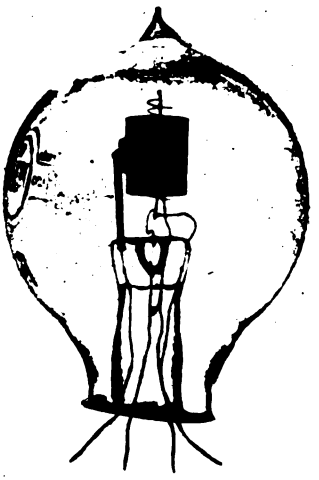

FIG. 3.—The Bulb Sealed Off.

FIG. 4.
The KA Valve.

FIG. 5.
The KB Valve.

After sealing off a terminal cap is attached to the valve with cement. This cap is usually of one or other of two patterns—the four-pin type cap, originally standardised on the "French" valves—or the spring contact type of cap which originated in the Naval and Air Force laboratories. These two types of cap are shown in Figs. 4 and 5 respectively which illustrate the KA and KB valves. The special type of cap shown on the KB type valve is particularly suited for short wave work as the complete valve and holder of this type gives a smaller effective valve capacity. Apart from this difference in mechanical construction the KA and KB types of valve are practically identical and are designed particularly for amplification, being especially suitable for use with high frequency amplifiers. They require about $3\frac{1}{2}$ volts on the filament and

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only 20–30 volts between the anode and filament for normal working. Characteristic curves taken on a valve of this type are shown in Fig. 6.

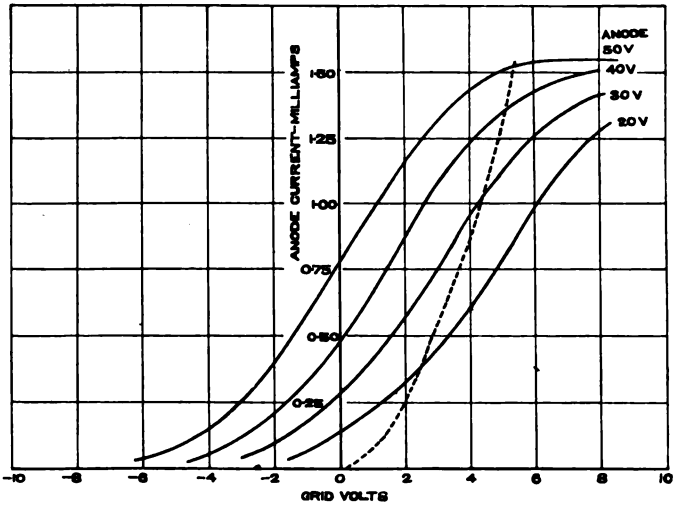

FIG. 6.—Characteristic Curves of the K Type Valve, with filament current = 0·6 A, and filament voltage = 3·3 V. The broken line = grid current × 100.

Before the caps are mounted the valves are subjected to a short "ageing" run, and afterwards to a careful testing process. In carrying out these tests the filament current is adjusted until an electronic emission of 2 milliamps, as indicated by the milliammeter in the plate circuit, is obtained using a given anode voltage. The filament voltage and current are then read off on appropriate instruments, and these must fall within certain predetermined limits or the valve is rejected. The high tension voltage applied to the anode is then reversed and a "backlash" test is made by observing the current flowing through the valve on a sensitive microammeter. This backlash current must not exceed 0·3 microampere. These tests are also repeated with various high tension voltages applied to the anode so as to obtain some indication of the slope of the anode-voltage anode-current curve.

FIG. 7.—The O/30 Transmitting Valve.

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In the construction of larger valves for transmission purposes slight modifications are introduced into the above scheme, except in the case of the smallest transmitting valves made by this firm, viz., the O/20 and O/30

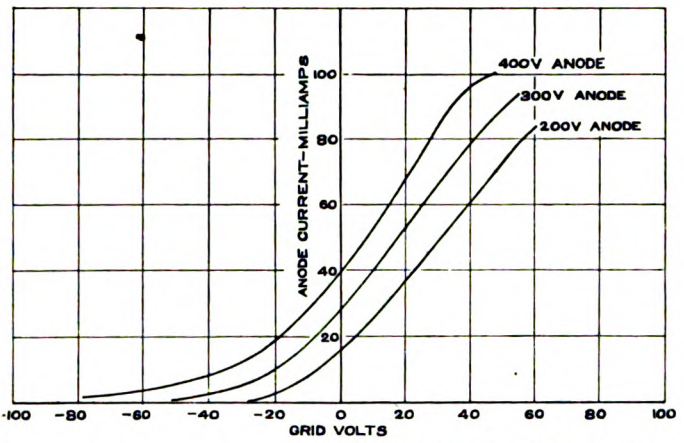

Fig. 8.—Characteristic Curves of O/20 valve, with filament current = 1·7 A, and filament voltage = 6·0 V.

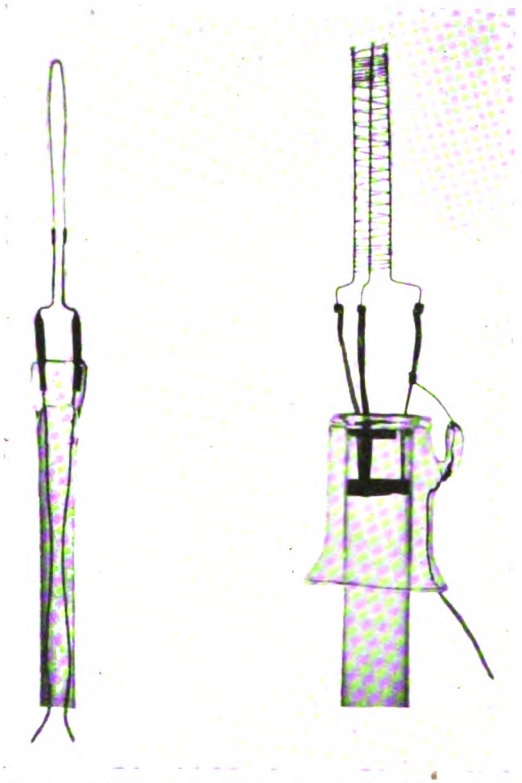

Fig. 9.—Grid and Filament of O/250 Valve, separately mounted ready for Sealing into Bulb.

types. These are of similar design to the R and K types of receiving valves with the exception of a slightly more robust design. A valve of the O/30 type is illustrated in Fig. 7. This valve is designed to operate on an anode voltage of between 600 and 1,200 volts with a filament current of 1·2 amperes at 6 volts. The anode of this valve will safely dissipate 30 watts under these conditions which means that an output of high frequency energy of at least this amount is obtainable in the circuit connected to the valve. Particular mention may also be made of the O/20 type of valve which is of similar design but will operate satisfactorily on an anode voltage of between 200 and 400 volts, the safe anode dissipation

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being 20 watts. Characteristic curves for one of these valves are given in Fig. 8.

Larger transmitting valves designed for safe energy dissipation of 100–150 watts (Type O/150), of 200 watts (Types O/250A and O/250B) and of 500 watts (Type O/500), are also manufactured by this firm. In these valves a different construction is adopted and use is made of the specially designed features claimed in British Patent 158720. This special construction provides exceptionally long insulating paths between both anode and grid and the filament. It also has the additional advantage of rendering possible the renewal of the valve filament by the makers, if the valve is returned with the bulb intact. The maintenance cost of valve installations may thus be very considerably reduced.

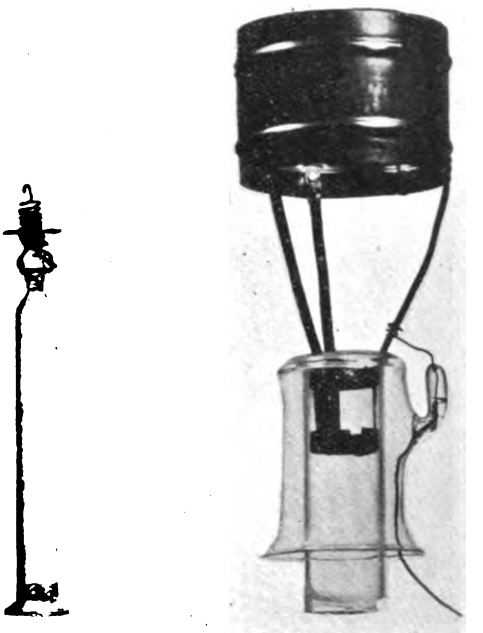

FIG. 10.—Anode and Filament Tension Spring, separately mounted before Sealing into Bulb.

The manner in which the electrodes of a power valve are built up to obtain these results may be seen from Figs. 9 and 10, which show the four component parts of such a valve mounted on their respective glass stems. Taking the filament first; this is of loop form and is mounted on two nickel strips on its own glass stem which is of such a diameter that it will pass freely up the centre of the inner glass tube of the stem on which the grid is mounted without coming into contact with any of the grid supports or connections. The grid is formed of a spiral of nickel wire laced on to straight nickel supporting wires which themselves are carried by channel-shaped nickel strips held in place by friction on the inside of the glass tube of the grid stem. The flanged end of the glass stem carrying the filament is ultimately sealed on to the outer end of the inner glass tube of the grid supporting stem and this part is finally completely exterior to the valve bulb itself, which is sealed on to the flanged outer part of the grid stem. Similarly the tension spring which supports the loop of the filament from the other end of the bulb is attached to a narrow glass tube which passes centrally up, but separated from the inner glass tube which supports the anode of the valve from the opposite end of the bulb. There is thus

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in each case a double glass wall and a vacuous space between the anode and the grid terminal wires and the filament leads. The final appearance of one of these valves may be seen from Fig. 11 which illustrates a valve of the O/500 type designed for an anode voltage of 2,000, and requiring a filament circuit of 5·25 amperes at 17·5 volts. The overall length of such a valve is about 16 inches and the diameter of the bulb about 7 inches. With the exception of a greater length of anode grid and filament this valve is of the same type as the O/250, the parts of which have been illustrated in Figs. 9 and 10. By cutting through the tubes which project at opposite ends of the valve, the two small stems supporting the loop filament and its tensioning spring may be withdrawn from the valve and a new filament inserted in place, sealed into position and the valve re-exhausted. Some characteristic curves taken on a power valve of the O/500 type are shown in Fig. 12.

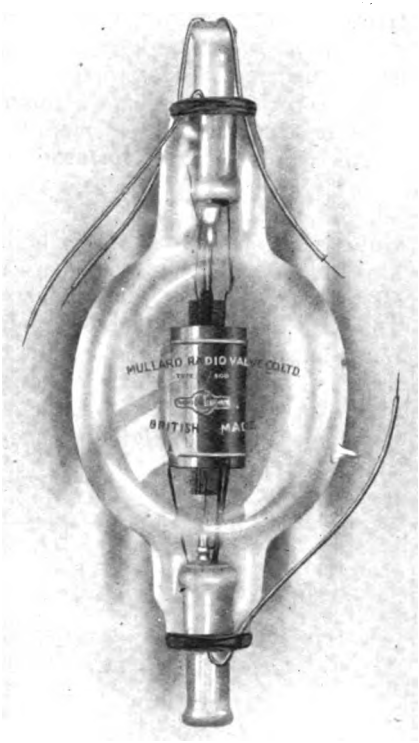

FIG. 11.—Transmitting Valve, Type O/500.

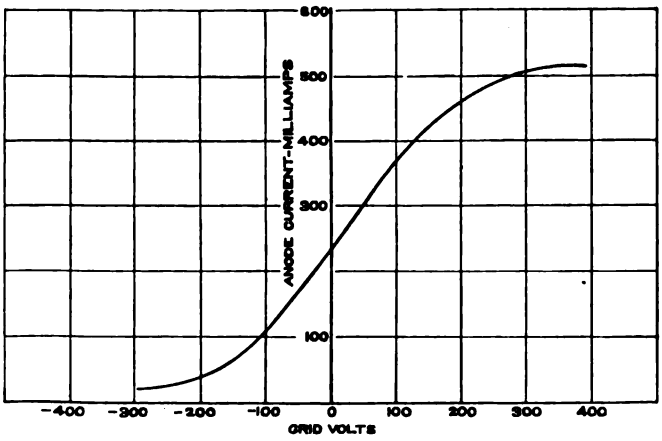

FIG. 12.—Characteristic Curve of O/500 Valve.
Anode voltage = 1,600 V.

Two-electrode valves for rectifying high tension alternating currents are also manufactured to similar designs. A small and a large pattern rectifying valve are illustrated in Figs. 13 and 14, which show valves designed for anode dissipations of 30 and 250 watts respec-

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tively. The U/500 type of rectifying valve built on these lines will pass an anode current of 0·55 ampere.

Quite recently further developments have been made in the manufacture of power valves capable of dealing with still larger amounts of energy without overheating the anode. These valves are enclosed in a silica bulb and have anodes designed on a much larger scale than those here illustrated. They are built up of narrow molybdenum strip plaited into a hollow cylindrical form. The general design of filaments and grids for these valves does not differ materially, except in dimensions, from that used for smaller valves. The most striking feature of these valves is their small size for the power they are capable of handling, since the silica bulb is made cylindrical in form and very little larger than the anode. This construction is possible on account of the high melting point of silica, but this high melting point naturally renders their manufacture much more difficult since the material can only be worked in an oxyhydrogen flame. The exhaustion of these high power valves also introduces special problems, and extensive research work is in progress as a result of which valves capable of handling very large outputs will be available.

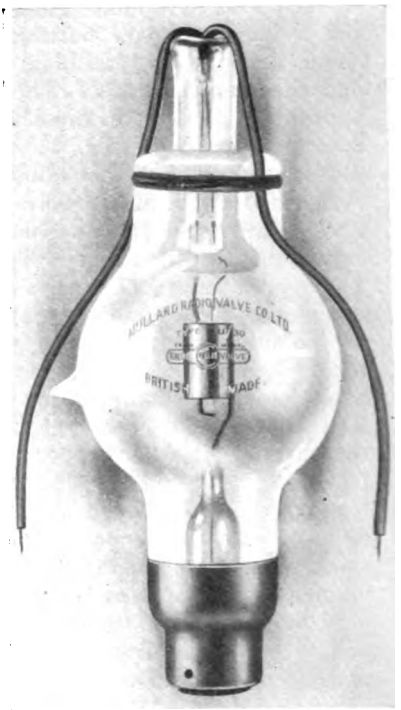

Fig. 13.—Rectifying Valve, Type U/30.

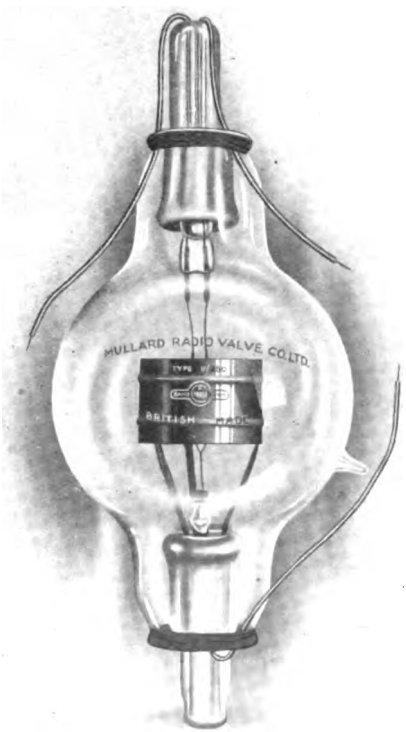

Fig. 14.—Rectifying Valve, Type U/250.

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The Reception of Wireless Waves on a Shielded Frame Aerial.*

By ALAN A. CAMPBELL SWINTON, F.R.S.

The following experiments were recently carried out by the writer in his laboratory in London, in order to test a suggestion made by Mr. N. P. Hinton, a member of the Sub-Committee on Directional Wireless of the Radio Research Board, that something of the nature of a wireless telescope with improved direction finding properties, might be made by placing a frame aerial in a large metal tube or wire spiral, open at the ends.

Particulars are published with the permission of the Radio Research Board.

The frame employed was a circular one, 1 foot in diameter, with 100 total turns of No. 20 S.W.G. cotton-covered copper wire all the turns bunched together, with a four-way switch so arranged that the number of turns in use could be diminished to twenty, forty or eighty turns, as desired.

With eighty turns in use, and with an adjustable condenser connected across its ends, this frame records, in London, the spark emission from the Eiffel Tower in Paris loudly when coupled to a five-valve resistance amplifier connected to a three-valve transformer-coupled note magnifier, and has fairly good directional properties. All the experiments were made with spark emission from Paris, which has a wavelength of 2,600 metres.

The shielding tube first employed consisted of an oblong wooden frame of square section, 18 inches wide, 18 inches deep, and 4 feet long, wound round with No. 18 S.W.G. bare copper wire spaced 1 inch apart, and connected to earth. With the ends of the tube open, and with the extremities of the square copper spiral unconnected, the frame, when placed within the tube, gave signals from Paris of approximately the same strength as outside of the tube. When, however, the ends of the spiral were connected together, so as to form a closed circuit, the signals received on the frame were considerably weakened, say by about 50 per cent., and this weakening was accentuated so that the signals only retained about 25 per cent. of their original strength, by short circuiting the individual spirals with four longitudinal copper wires along the corners of the tube. It was found, however, that the tube itself possessed no appreciable directional screening effect upon the frame, it making no detectable difference in what direction the tube was pointed provided the frame itself was in the plane pointing to Paris. This continued to be the case even when the open ends of the tube were closed by grids of copper wire connected at numerous points to the spiral, the putting on or removal of these grids making no detectable difference in the strength of the signals.

Finally the whole tube, including its ends, was completely covered in with iron wire netting of about $\frac{1}{2}$ inch mesh, in contact with the copper spiral and end grids, when it was found that though the signals were slightly further diminished in intensity, say to about 20 per cent. of their original strength, Paris could still be easily heard on the frame, which continued to have directional properties quite irrespective of the position of the wire netting covered tube.

It would appear from the experiments that while completely enclosing the frame in a conducting network considerably damps the currents in the frame, and thus diminishes the strength of the signals, such conducting network by no means entirely screens the frame from incoming waves of the 2,600 metre length sent out on the spark emissions of the Eiffel Tower. This result would appear to be dependent on the considerable wavelength tested, as copper wire grids such as are mentioned above, with the wires parallel to the plane of polarisation of the waves, pretty well completely screen off the very short waves of a few centimetres length, such as were used in the original lecture room experiments with Hertzian waves as shown many years ago by Sir Oliver Lodge.

Further experiments were made with the frame placed within a copper box in the form of a cube of 2 feet dimensions in each direction, made of sheet copper about $\frac{1}{16}$ of an inch in thickness. This box was completely closed in with soldered joints excepting on one side, which was open, but could be closed by means of a close-fitting lid also made of similar sheet copper.

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* Paper read before Section A of the British Association at Edinburgh on Thursday, September 8th, 1921.

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In all the experiments the copper box was connected to earth. The same circular frame aerial, 1 foot in diameter, used in the previous trials, was employed, but a more compact transformer-coupled six-valve amplifier was used in place of the five-valve resistance amplifier and the separate three-valve note magnifier.

Preliminary experiments, in which only the frame aerial was enclosed in the copper box, the amplifier, tuning condenser, telephone receiver and batteries being outside, having proved unreliable owing apparently to the outside apparatus picking up the waves irrespective of the frame, it was decided to put the whole of the apparatus and connections, as well as the frame, inside the box, and to listen to the telephone receiver through a ½ inch rubber tube passed into the box through a round hole in the latter. Considerable trouble was experienced in getting the apparatus to work properly under these conditions, the close proximity of the frame and the amplifier causing reactions, that were apt to lead to automatic howling, but with care clear signals were again obtained.

Experiments were again repeated with the 2,600 metre spark emission from the Eiffel Tower.

Though putting the frame and other apparatus into the box greatly reduced the strength of the received signals, still, when the frame was pointed in the right direction, with the open side of the copper box turned towards Paris, the signals could be heard quite easily. They were probably only about 5 per cent. of the strength obtained with the frame completely unshielded.

On closing up the open side of the box with the copper lid, it was found that as the lid was put on, the signals further gradually diminished in strength. They were, however, still distinctly audible so long as the narrowest possible slit or opening was left. Indeed, they only disappeared, and did so quite suddenly, when the edges of the lid came into actual contact with the box so as to form a closed continuous electrical conductor round the frame. With the lid quite closed, and making good electrical contact all round, no trace of the signals could be heard.

Experiments were also tried with a lid consisting of thin tin-foil pasted on wood, in place of the copper lid. This lid was just as effective as the copper one in stopping the signals. When the tin-foil lid completely closed the aperture and made good contact all round with the copper box, no trace of any signals could be obtained.

As mentioned, all these results were obtained with the open side of the box facing Paris, but exactly similar results, with no distinguishable difference as regards the strength of the received signals, were obtained when the box was turned round so that its open side was pointing in the exactly opposite direction from Paris. By such means it is therefore not possible to ascertain the absolute direction of the waves, any better than with an unshielded frame.

With the box turned so that its open side pointed in a direction at right angles to the direction of Paris, either to the right or to the left, but with the frame pointing in the direction of Paris, no signals at all could be heard, though the side of the box was completely open; but with the box so placed that its open side pointed in a direction making an angle of 45° with the direction of Paris, with the frame pointing in the same direction or more towards Paris, the signals could be heard, though faintly, being reduced to some 1 per cent. of their value with the frame completely unshielded.

For any signals to be heard it was, however, essential that the relative positions of the box and frame were such that a prolongation of the plane of the frame towards or away from Paris, no matter which, came out of the open side of the box clear of the copper sides.

With box turned up so that its open side pointed to the sky, with the vertical frame pointing to Paris, the signals could be heard at about 1 per cent. of their full unshielded value and disappeared when the lid was put on, in exactly the same way as when the open side of the box was pointing to, or directly away from Paris.

From these experiments it would appear that waves of the length and strength of those experimented with do not penetrate into a completely closed metallic box to a sufficient extent to give audible signals with a frame aerial and amplifier of the description used, even if the side of the box facing the source of the waves is only closed with tin-foil. Further, it would seem that the screening effect is largely a matter of a closed electrical conducting circuit in that portion of the box that surrounds the periphery of the frame, the smallest break in the electrical conducting continuity interfering largely with the screening effect.

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That this is so, is shown by further experiments made with a flat sheet of tin plate, 5 feet in length and 8 inches wide, bent so as to form a cylinder. This was placed over the frame so that the axis of the cylinder coincided with that of the frame. With the ends of the tin-plate sheet overlapping, but not in electrical contact, the effect in reducing the strength of the signals was small, but immediately increased considerably, so that the signals were reduced to about 20 per cent. of their original strength, when the ends of the sheet were allowed to touch so as to form a continuous conducting ring round the periphery of the frame. Contracting the diameter of the ring by sliding the overlapping ends of the plate so that the ring was closer to the frame all round still further reduced the strength of the signals, till when the ring was touching the insulated wires of the frame all round, the signals very nearly disappeared. This indicates that the effect is not merely a question of screening, but also of eddy current damping which was further shown by contracting the tin-plate cylinder still further, and placing it inside the frame, where it again had the effect of largely reducing the strength of the signals. That damping enters largely into the matter was also proved by placing a large flat copper plate close up to one side of the frame, where it could have no screening but only a damping effect, which also greatly diminished the strength of the signals.

The result obtained with the frame inside the copper box in getting signals of equal strength with the open side of the box facing away from the source of the waves, as when the open side faced towards such source, may perhaps be of some interest from the point of view of theory in throwing some light upon the mechanism of electro-magnetic wave phenomena, inasmuch as it gives evidence that in addition to what is analogous to a "push" upon an aerial in front of the wavefront, there is also something of the nature of a "pull" upon an aerial behind the wavefront.

Otherwise, the experiments go to show that, at any rate upon the small scale employed, the use of a shielding tube or box does not assist in improving directional reception. It is possible, however, that if tried on a larger scale, with much more space between the frame and the shield, so as to avoid damping, the results might be different.

Notes.

Personal.

Mr. H. G. Thomson, who resigned from the Edison Storage Battery Company in 1919 to form the Transportation Engineering Corporation of which he was elected President, has been appointed Sales Manager of the American Radio and Research Corporation, Medford Hills, Mass. [3798]

Paulino Solorvano has been appointed Director-General of Communications of Nicaragua with headquarters at Managua, *vice* T. Tijerino, appointed Consul-General of the Nicaraguan Government at New York. [4011]

Mr. Joseph D. R. Freed who, during the war, was Radio Engineer at the Radio Test Shop, U.S. Navy Yard, Washington, D.C., and subsequently for over two years Designing Engineer and then Assistant Chief Engineer of the Wireless Improvement Company, has organised the Radio Manufacturing Company, Executive Office, 156, Fifth Avenue, New York, N.Y., which company will manufacture radio apparatus of all kinds. Mr. Freed will further act in the capacity of Consulting Radio Engineer. [4013]

A. Stachel has been nominated Chief of the Telegraph, Telephone and Wireless Section of the Federal Ministry of Communications for Austria. [4024]

Mr. Peter Cooper Hewitt, the distinguished American scientist and inventor, died on Thursday, August 25th, at the American Hospital, Neuilly. He was in his 61st year, having been born at New York on March 5th, 1861. [4030]

Mr. Thomas Thomassen Heftye, Director-General of the Norwegian Telegraph Administration, died on September 18th, as the result of a railway accident. [4121]

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Legislation.

COMMERCIAL SERVICES FROM NAVY STATIONS.—The House of Representatives (U.S.A.) has passed a bill authorising the Secretary of the Navy to use all the radio stations of that department for the transmission of press messages and private commercial messages. [3797]

ADHESION TO THE RADIOTELEGRAPHIC CONVENTION.—The Polish Republic and the Danzig Free State have both signified their adherence to the Radiotelegraphic Convention and to the service regulations attached thereto. Certain reservations have been made in connection with Poland. [4023]

NEW RADIO LAWS FOR SWEDEN.—Under date of May 13th, 1921, a Royal Order has been made concerning the use of radiotelegraphic or telephonic installations on board foreign vessels in Swedish waters. It provides :—

(1) "That radio installations on board foreign vessels may only be used in the neighbourhood of Swedish ports with the special authorisation of the Director-General of Telegraphs in concert with the Chief Naval Officer and under strict observation of the detailed regulations prescribed by the Director-General of Telegraphs.

(2) "That radio installations on foreign vessels within 10 miles of a Swedish coastal radio station may only be used in cases of distress or for communication with the nearest coast station.

(3) "The Director-General of Telegraphs in consultation with the Chief Naval Officer may forbid or restrict, except in cases of distress, the use of wireless installations on board foreign vessels in other areas of Swedish territorial waters than are covered under Section 2 above." [4025]

THE NEW AUSTRALIAN NAVIGATION ACT, which comes into operation on October 1st, requires that every foreign-going or Australian trade ship, and every ship engaged in the coasting trade, which carries more than twelve passengers, or which, in the case of other ships, is of 1,000 tons gross tonnage or upwards, shall carry wireless apparatus as well as operators and watchers, unless specially exempted from doing so. [3698]

Every private wireless station in France is to be taxed 10 francs (4*s.* 5*d.*). [1657]

MARCONI WIRELESS PATENTS.—A verdict in favour of Marconi's Wireless Telegraph Co., Ltd., and the Compania Nacional de Telegrafia Sin Hilos has been given in the Spanish Courts as the result of a joint action brought by these companies against the Compania Ibericia de Telecommunicacion for infringement of patents relating to thermionic valves. [3810]

New Wireless Stations and Services.

NEW CANADIAN RADIO STATIONS.—The Alaska Wireless Telegraph Company is considering the possibility of introducing a wireless service between Edmonton, Alberta, Can., and Fort Norman. The Canadian Government is installing four wireless receiving stations between Peace River Crossing and the Arctic Ocean. [3826]

The radio station maintained at the offices of the *New York Times* has now been equipped with dictaphone receiving apparatus for the reception of press news direct from Bordeaux and Nauen at speeds up to 100 words per minute. A balanced loop aerial system is employed which considerably reduces interference from atmospherics. [3832]

THE FEDERAL TELEGRAPH COMPANY, U.S.A., state that their wireless stations at San Francisco and Portland are now ready for service. An additional station is also to be erected at Los Angeles. [3833]

NEW VENEZUELAN WIRELESS STATION.—It is reported that the erection of the towers for the new wireless station at Maracaibo (Venezuela) has been completed and that the station is nearly ready for commercial operation. The towers are 164 feet high and the normal sending radius will be about 800 miles by day and 1,600 miles by night. [3866]

THE RADIO CORPORATION OF AMERICA has announced that its new Radio Central station at New York is nearly ready for opening. Two of the arms of the antenna have been completed using twelve steel towers 400 feet high. Two Alexanderson H.F. alternators have been installed. [3867]

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The S.S. *Majestic*, which is being built for the White Star Line and is now nearing completion, will carry three wireless installations the largest of which will be capable of maintaining permanent communication with both America and England during the entire voyage across the Atlantic. The lifeboats include two motor boats equipped with wireless. Elaborate submarine signalling gear has also been installed. [4029]

WIRELESS SERVICE FOR LEAGUE OF NATIONS.—A special wireless telegraph service has been instituted by Marconi's Wireless Telegraph Company, Ltd., for the second assembly of the League of Nations at Geneva. The opening of this service, which was originally fixed for September 5th, has been pushed forward and actually took place on August 30th so as to render it available for the meeting of the Council of the League which is considering the Upper Silesian problem. Some further particulars may be found on p. 535 of this issue. [4026]

CHICAGO WIRELESS TELEPHONE SYSTEM OPENED.—The Chicago Municipal Wireless Telephone System, constructed under the supervision of W. G. Keith, City Commissioner of Electricity, to connect all police and fire stations, has been put in operation, and initial tests have proved satisfactory. The main sending and receiving station is on the roof of the City Hall. Commissioner Keith stated that ultimately there would be receiving stations on all beats to enable policemen to receive messages from stations or from headquarters. [4040]

Commercial and General.

A close working agreement between the Swedish and English interests has been established in the field of wireless telegraphy. The Swedish Radio Company and Marconi's Wireless Telegraph Company have been amalgamated into a new company which will still be called the Swedish Radio Company. [4032]

From the *Telefunken Zeitung* we learn that in April the speed of transmission from Nauen to Marion (U.S.A.) was increased from 50 to 80 words per minute. Nauen used the 400 kW set with a wavelength of 12,600 metres and operated the signalling choke coil from a Wheatstone transmitter through a special relay. In America a photographic recorder was employed. [3749]

THE INSTITUTION OF ELECTRICAL ENGINEERS.—At a meeting of the Privy Council, held at Buckingham Palace on Wednesday, August 10th, 1921, the petition of the Institution for a Royal Charter of Incorporation was approved and a Royal Charter has now been granted. His Majesty the King has also been graciously pleased to intimate his willingness to become a Patron of the Institution. [3876]

WIRELESS TRANSMISSION OF PHOTOGRAPHS.—According to *Telegraph and Telephone Age* some tests have recently been made of the transmission of photographs and written messages between the United States and France. The transmission was effected from the Naval Radio Station at Annapolis. The results are stated to have been successful. [4012]

A NEW PORTABLE WIRELESS RECEIVER.—The latest development in portable wireless receivers has just been placed upon the market by the Westinghouse Electric and Manufacturing Company, of East Pittsburgh, Pa., U.S.A., under the trade name of "Aeriola Jr." The complete outfit weighs but five pounds, and merely requires to be connected to a single wire aerial and to an earth wire, the remainder of the auxiliary apparatus being contained in the one case. All tuning operations are effected by means of a single movable arm. [4045]

WIRELESS TELEPHONY IN SOUTH AFRICA.—The Union Government is experimenting with wireless telephony with the view of linking the chief centres. Communication has been successfully established between Johannesburg and Bloemfontein. It is hoped to extend the system gradually, thus lessening the cost of ordinary telegraphic and telephonic working, which is unusually high owing to maintenance charges over immense distances. [4031]

LYONS WIRELESS STATION.—As a result of a violent storm recently the wireless station at Lyons has been considerably damaged. Two of the steel towers, which are over 600 feet in height, crashed to the ground. [3879]

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Review of Radio Literature.

1. Abstracts of Articles and Patents.

(A.) General Articles descriptive of Installations, etc.

2430. **Gesellschaft für drahtlose Telegraphie.** Sending Arrangement for Wireless Telegraphy. (*German Patent* 317541, October 25th, 1918, relating to *German Patent* 304361. Patent granted December 24th, 1919; *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, p. 60, January, 1921.)

One or more oscillating circuits tuned to the fundamental frequency are connected to intermediate points of the loading inductance of an antenna circuit (see Fig. 1).

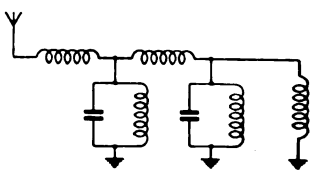

FIG. 1.

2431. **H. Thurn.** Nauen. (*Archiv für Post und Telegraphie*, 7, pp. 253—279, July, 1921.)

A semi-popular but very complete and well illustrated account of the development and present equipment of the station at Nauen.

2432. The new Dutch Station at Kootwijk. (*Radio Nieuws*, 4, pp. 196—198, July, 1921.)

A few details of the high-power station in course of erection between Assel and Kootwijk.

2433. The Present State of Large Telefunken Stations being built in Holland, Java and Argentine. (*Telefunken Zeitung*, 4, pp. 17—21, May—June, 1921.)

A descriptive illustrated article giving a few details of the erection of these stations.

2434. The Telefunken 10 kW Triode Transmitter in Prague. (*Telefunken Zeitung*, 4, pp. 27—29, May—June, 1921.)

An illustrated description.

2435. Foreign Radiotelegraph Progress. (*Electrician*, 87, pp. 185, 190, August 5th, 1921.)

Notes of the statements made by **Mr. Pike Pease** in the House of Commons relative to the high-power stations of the United States, Germany and France, and the equipment of the Leafield station.

2436. The Clifden Station. (*Engineer*, 132, p. 193, August 19th, 1921.)

A short note dealing with the fuel consumption at the Clifden radio station.

2437. The Lyons Radio Station. (*Radio News*, 3, pp. 6—8, July, 1921.)

An illustrated description of the station and its equipment.

2438. **R. R. Smith.** The Clark Radiophone. (*Radio News*, 3, pp. 108—109, August, 1921.)

An illustrated description of the installation at Clark University (U.S.A.) with details of the results obtained on various aerials.

2439. **P. Boucherot.** Radio Central. (*World Wide Wireless*, 2, pp. 3—5, August, 1921.)

A short description of the progress in the building of the high-power radio station near New York.

2440. The Paris Radio Centre—June, 1921. (*Radioélectricité*, 2, pp. 14—24, July, 1921.)

An account of the progress of the work in the building of the high-power radio central station at Sainte Assise near Paris. Charts are given of the progress in the building of the towers and of the installation of other parts of the apparatus with photographs of the buildings in course of erection and of the machinery and apparatus already installed.

2441. **L. V. Bournat.** The Most Powerful Station in the World. (*Technique Moderne*, 13, pp. 49—54, February, 1921. *Radioélectricité*, 1, p. 145D, June, 1921—Abstract.)

General descriptive article on Sainte Assise station with a comparison with Nauen.

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2442. The Largest Radio Station in the World. (*Technique Moderne*, 13, p. 32, February, 1921. *Radioélectricité*, 1, p. 145D, June, 1921—Abstract.)
A description of the Lafayette Station.

2443. **M. B. Sleeper.** Commercial Practice applied to Experimental Radio Stations. (*Radio and Model Engineering*, 1, pp. 11—12, June, 1921.)

2444. **G. Viard.** The High-power Radio Station at Nauen, near Berlin. (*Genie Civil*, 78, pp. 405—409, May 14th, 1921.)
Gives a summary of the history of the station followed by a description of the installation—alternators, frequency doublers, etc., with illustrations of some of the apparatus.

2445. **F. Linke.** The Alexanderson High-frequency Machine and the High-power Station at New Brunswick. (*Zeitschrift des Vereines deutscher Ingenieure*, 65, pp. 467—469, July 30th, 1921.)
A general descriptive article on the lines of Abstracts Nos. 2084, July, 1921; 1333, January, 1921; and 2492 in this issue.

2446. The Opening of the Leafield Wireless Station. See pp. 509—523 in this issue.

2447. **D. Sinclair.** The Wireless Stations of the British Commercial Airways. (*Wireless World*, 8, pp. 798—810, February 19th; p. 830, March 5th, 1921. *Radioélectricité*, 1, p. 147D, June, 1921—Abstract.)
An illustrated description of the stations and plant.

2448. Austrian Portable Radio Sets. (*Scientific American*, 122, p. 697, June 26th, 1920—Abstracted from *Elektrotechnik und Machinenbau.*)

2449. **H. P. Davis.** Radio—Its Future. (*Electric Journal*, 28, p. 109, April, 1921.)

2450. **W. S. Rugg.** Radio—Its Relation to the Electrical Industry. (*Electric Journal*, 28, pp. 109—110, April, 1921.)

2451. **E. W. Stone.** Radio Telephony. (*Radio News*, 3, p. 24, July, 1921.)
A general article.

2452. **E. Reinhard.** The Building of Large Radio Stations. (*Telefunken Zeitung*, 4, pp. 8—14, March, 1921.)
A discussion of the conditions for the successful erection of a large station, the area required, the nature of the foundations, water supply, necessary surveying, buildings, cooling pond, road-making, etc.

2453. **W. Bragg.** Electrons and Ether Waves. (*Discovery*, 2, pp. 224—228, September, 1921.)

2454. **H. Zickendraht.** Wireless Telephony. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, pp. 369—372, May, 1921.)
A report of reception tests made at Bâle University on various telephonic transmissions. The antenna was a 2-wire **T** 18 metres high and 80 metres long, using a crystal detector and a 2-stage low-frequency amplifier. The Königswusterhausen valve transmitter gave very clear speech and music, but the Poulsen arc at the same station was not good in spite of its loudness. After preliminary improvements the high-frequency alternator tests from Nauen gave good results. The causes of defective reproduction are discussed and also the interference due to other stations heterodyning with the desired transmission, *e.g.*, Nauen $\lambda = 4{,}700$, and Coltano $\lambda = 4{,}450$ metres.

2455. **Lorenz Company.** Wireless Telephony with the Poulsen Generator. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, pp. 373—375, May, 1921.)
Gives a few details of the apparatus employed in the Easter Concert transmitted from Königswusterhausen. The arc was of the 4 kW type giving 30 amperes into the antenna at a wavelength of 3,700 metres. The microphone current passes round the iron core of an inductance in the antenna circuit; the voice causes variations of the microphone current which alters the permeability of the iron core and thus detunes the aerial. Further details are promised.

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2456. A New Wireless Station for China. (*Electrical Review*, 88, p. 554, April 29th, 1921.)
Refers to the construction of a high-power wireless station east of Pekin and also to other contemplated radio stations in Shantung.

2457. The New Paris Radio Station. (*Radio News*, 2, p. 606, March, 1921.)
A summary of the chief features of the proposed radio station to be built at Sainte-Assise.

2458. A New Use for Radio. (*Radio News*, 2, p. 856, June, 1921.)
Relates to the broadcasting of radio telephone music from the Union College Radio Club Station.

2459. Golden Gate Pilots Use Radiophones. (*World Wide Wireless*, 2, p. 17, July, 1921.)
The port pilot ships for guiding vessels through the Golden Gate have now been equipped with wireless telephones to expedite communication.

(B.) Spark Gaps and Spark Transmitting Apparatus.

2460. **M. Wolfke.** Reversal of Rectification in Spark Gaps with Air Blast. (*Physikalische Zeitschrift*, 22, pp. 123—125, February 15th, 1921.)
In a point and plate gap the rectification is very small and uncertain in direction unless the gap is submitted to a powerful air blast. With gradually increasing blast the direction may reverse once or twice, but with a strong blast the rectification is very good and is always in the direction from point to plate.

2461. **F. Trey.** The Effect of Electric Wind on Spark Gaps. (*Physikalische Zeitschrift*, 22, pp. 406—409, July 15th, 1921.)
In some cases radium or ultraviolet light not only causes the spark to occur but if brought nearer or strengthened acts in the opposite sense and inhibits the spark. This is shown experimentally to be due to the production of an electric wind.

2462. **E. Meyer.** On the Influence of Impurities on Sparking Voltages in Air. (*Annalen der Physik*, 65, pp. 335—368, June 28th, 1921.)

2463. **H. Stücklen.** On the Influence of Water-vapour on Spark Voltage. (*Annalen der Physik*, 65, pp. 369—377, June 28th, 1921.)

2464. **R. Bosch Aktien-Gesellschaft.** Quenched Gap Generator. (*German Patent* 317021, May 19th, 1917. Patent granted January 7th, 1920. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 380, November, 1920 - Abstract.)
An arrangement for quenching a spark gap magnetically, the electromagnet being automatically energised at each spark.

2465. **J. Marsten.** Some Notes on Quenched Gap Transmitters. (*Radio News*, 2, p. 689, April, 1921.)

2466. **F. Lowenstein.** Spark Gap. (*British Patent* 157258, January 10th, 1921. Convention date August 25th, 1914. Patent not yet accepted.)
A multiple spark gap in which the number of effective elements can be varied with a switch. The gaps have cylindrical, conical or spherical fluted surfaces.

2467. **A. J. Klonck.** A Synchronous Rotary Spark Gap. (*Wireless Age*, 8, p. 23, August, 1921.)

2468. **Gesellschaft für drahtlose Telegraphie.** Wireless Transmitters. (*British Patent* 147436, July 7th, 1920. Convention date December 6th, 1913. Patent not yet accepted.)
In order that spark transmitters may be used with heterodyne receivers successive sparks are timed so that the resulting wave-groups occur in correct phase-relation.

2469. **R. B. Goldschmidt.** Continuous Wave Transmitter. (*French Patent* 508122, January 3rd, 1920. Published October 2nd, 1920.)
The specification describes a method of exciting a high-frequency oscillating circuit by a primary circuit by means of a direct or inductive coupling. The damping of a condenser discharge is obtained by employing a resistance which varies with the time, for example, a self-inductance instead of relying on the resistance of the spark path.

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2470. **E. von Lepel.** Apparatus for the Generation of Electrical Oscillations. (*German Patent* 302502, April 7th 1914.)

A method of generating electrical oscillations by means of a direct voltage source and condensers with rotating or vibrating plates. A system of choking coils prevents the discharges from passing through the source. Modulation voltages may be introduced in the circuit *via* coil M (Fig. 2).

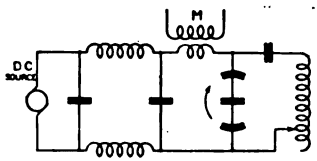

FIG. 2.

2471. **W. S. Lemmon.** The Resonant Converter. (*Q.S.T.*, 4, pp. 17—21, May, 1921.)

An illustrated description is given of a commutator set for converting from D.C. to A.C. The application of the arrangement to spark and valve transmission is dealt with.

2472. **F. H. Newman.** A New Form of Wehnelt Interrupter. (*Proceedings of the Royal Society*, 99A, pp. 324—336, July 1st, 1921.)

The interrupter consists of a platinum wire immersed in a saturated solution of ammonium phosphate. The whole is contained in an aluminium vessel which acts as the cathode. Less heating is claimed. Some oscillograms are included with the paper.

2473. **G. Holst** and **E. Oosterhuis.** The Influence of the Gas on the Operation of a Mercury Break. (*Physica*, 1, pp. 56—57, May, 1921.)

An experimental investigation of the effect of different gases on the spark-length of an induction coil. The differences are very great, *e.g.*, 1·7 cm with 85 per cent. argon and 15 per cent. nitrogen, 11·5 cm with coal-gas or hydrogen. The authors explain this by the difference in the ability of the gases to form clusters or heavy ions of small mobility.

(C.) Arc Apparatus.

2474. **H. Marchand.** The Poulsen System used at the Radio Station at Bordeaux. (*La Nature*, 49(1), pp. 293—296, May 7th, 1921.)

An illustrated article dealing with various types of Elwell Poulsen arc equipment.

2475. **J. Cohen.** Wireless Telegraphy. (*British Patent* 157782, January 10th, 1921. Convention date, November 13th, 1915. Patent not yet accepted.)

In an arc generator system two oscillatory circuits are shunted across the arc, and the time constants L/R of the two circuits are so adjusted in relation to one another, that when both circuits are closed oscillatory current will flow in one circuit but not in the other.

2476. **Gesellschaft für drahtlose Telegraphie.** Wireless Signalling. (*British Patent* 147428, July 7th, 1920. Convention date, July 3rd, 1914. Patent not yet accepted.)

Oscillations generated by an arc are transmitted to an aerial through a static frequency raiser and may be modulated at the same time by currents in additional windings.

2477. **W. A. Eaton.** Description of a Uni-wave Signalling System for Arc Transmitters. (*Electric Journal*, 18, pp. 114—115, April, 1921. *Electrical World*, 77, p. 1175, May 21st, 1921. *Science Abstracts*, 24B, pp. 362—363, Abstract No. 747, July 30th, 1921—Abstract.)

The necessity for the development of a uni-wave signalling system is detailed and the essential equipment is discussed.

2478. Improvements in Arc Generators. (*L'Elettrotecnica*, 8, pp. 252—253, April 15th, 1921.)

Describes arrangements of condensers and resistances and choking coils devised by **L. F. Fuller** for the protection of the dynamo supplying the arc.

2479. **C. Lorenz Akt.-Gesellschaft.** A Small Poulsen Arc Wireless Telephone Set. (*Elektrotechnische Zeitschrift*, 42, p. 550, May 26th, 1921.)

A brief description with photograph of a set exhibited by the Lorenz Company at the Essen exhibition. The whole is contained in a small box with the exception of the arc which stands on the box and takes 2 amperes at 220 volts. Range 15 km without amplifier, using aerials 20 metres high and 300 cms capacity. A somewhat similar set using a triode oscillator is also described.

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2480. **T. D. Haig.** The Arc or Continuous Wave Transmitter. (*Radio News*, 2, pp. 520—521, February, 1921.)

A general account of the mode of operation of an arc transmitter.

2481. **A. de la Bruère.** Continuous Wave Transmitter. (*French Patent* 509966, May 30th, 1919. Published November 24th, 1920.)

The specification relates to luminous arc apparatus employed in the emission of electromagnetic waves. The chamber in which the arc is formed is connected by a tube with a reservoir containing a liquid which will not dissolve the gas which constitutes the special atmosphere within which the arc is formed, or which will only dissolve the said gas in a very small proportion. The reservoir is connected at its lower end by a tube with a second reservoir to receive the liquid which is forced out of the first reservoir by the gas, so that the said gas can be maintained under a predetermined pressure.

2482. **D. G. Little.** Continuous Wave Radio Communication. (*Electric Journal*, 28, pp. 124—129, April, 1921. *Electrical World*, 77, p. 1383, June 11th, 1921—Abstract.)

Illustrated descriptions are given of small and large arc apparatus, H.F. alternators and various patterns of valve transmitters.

2483. **Q. A. Bracket.** Radio Arc Transmitters. (*Electric Journal*, 28, pp. 142—146, April, 1921.)

Various patterns of arc apparatus are briefly described and illustrated.

2484. **C. R. Leutz.** A New Arc Transmitter. (*Radio News*, 3, p. 99, August, 1921.)

An illustrated description of a 5 kW panel type installation designed for ship use.

2485. **D. R. Clemons.** Construction of a 1 kW Arc Converter. (*Radio News*, 3, pp. 103, 162, August, 1921.)

An illustrated description.

2486. **Compagnie Générale de Radiotélégraphie.** Continuous Wave Transmitter. (*French Patent* 504135, February 9th, 1918. Published June 25th, 1920.)

The invention consists in employing as the atmosphere surrounding the arc of an arc generator, hydrogen charged with petrol ether vapour. An apparatus is also described for causing the hydrogen to be charged with the said vapour in which the hydrogen is directed on to the surface of liquid petrol ether.

2487. **E. Mayer.** The Theory of the Poulsen Arc. (*Zeitschrift für technische Physik*, 2, pp. 18—28, January; pp. 40—49, February; pp. 73—81, March; pp. 94—105, April, 1921.)

A very long and detailed theoretical investigation of the effective value of the current, the power, efficiency, stability, etc., in an arc for oscillations of the first and second kind all based on the assumption of sine wave current and simple forms of characteristic. The paper was written in an internment camp in the United States.

2488. **J. F. Bront.** The Arc and Radio Telephone Transmitters. (*Radio News*, 2, pp. 868—869, June, 1921.)

Constructional details are given of low-power arc installations for experimental work.

2489. **P. O. Pedersen.** Some Improvements in the Poulsen Arc. (*Electrician*, 86, pp. 684—686, June 3rd, and pp. 714—716, June 10th, 1921. *Electrical World*, 78, p. 81, July 9th, 1921—Abstract.)

A series of investigations made by the author from 1914 to 1918 in an endeavour to elucidate the operation of the Poulsen Arc has resulted in certain improvements in the arc. The author deals with the investigation and the main results obtained as an explanation of the improvements which are described in the latter part of the article. Oscillograms of the arc are given, in verification of the theory proposed, and a description of a special water-cooled cooling shoe fitted to the cathode of the arc, to enable weaker magnetic fields to be used. (See also pp. 505—507 in this issue.)

2490. The Arc System in Radio. (*Scientific American*, 124, p. 343, April 30th, 1921.)

A short note setting out the advantages claimed for arc apparatus.

2491. **G. von Arco.** A Comparison of High-frequency Alternators, Arcs and Valve Transmitters. (*Telefunken Zeitung*, 4, pp. 5—8, March, 1921.)

A popular article in which it is claimed that the arc cannot maintain the constancy of

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frequency called for by the latest developments in receiving apparatus, involving multiple heterodyne methods. The increased selectivity and diminished damping of the receiving apparatus necessitates a greater constancy of frequency. It is claimed that to obtain equal loudness of signals and freedom from interference, the radiated power with an arc must be three times that from an alternator and ten times that from a valve transmitter.

(D.) High-frequency Alternators.

2492. **E. E. Bucher.** The Alexanderson System for Radio Communication. (*General Electric Review*, 23, pp. 813—839, October, 1920. *Electrical World*, 76, p. 1225, December 18th, 1920—Abstract. *Scientific American Monthly*, 2, pp. 161—166, October, 1920—Abstract.)

This paper has already been abstracted from the *Wireless Age*. (See RADIO REVIEW Abstract No. 1333, January, 1921, and 1809, May, 1921.)

2493. **Société Française Radioélectrique.** Wireless Signalling. (*British Patent* 147465, July 7th, 1920. Convention date July 9th, 1919. Patent not yet accepted.)

Relates to the use of several H.F. alternators in parallel with condensers in series with each machine to maintain the correct phase relations.

2494. **Société Française Radioélectrique.** Wireless Transmitting Apparatus. (*British Patent* 165037, July 7th, 1920. Convention date October 16th, 1919. Patent not yet accepted.)

Relates to an arrangement of high-frequency alternators connected in parallel, each alternator being connected to the busbars through a condenser. The signalling key may be connected across the inductance coupling the busbars to the transmitting aerial system.

2495. **Ateliers de Constructions Électriques du Nord et de l'Est.** High-frequency Alternator. (*French Patent* 502925, June 27th, 1916. Published May 29th, 1920. *Radioélectricité*, 1, p. 85D, January, 1921—Abstract.)

The specification describes forms of windings for high-frequency alternators.

2496. **Compagnie Française pour l'Exploitation des procédés Thomson-Houston.** High-frequency Alternator. (*French Patent* 507092, December 5th, 1919. Published September 4th, 1920.)

This specification describes a high-frequency inductor alternator. The field magnet is provided with a number of independent exciting windings, each of which is capable of furnishing the field excitation for full load. The windings are arranged so that they can be easily repaired or renewed. Further particulars may be obtained from the corresponding *British Patent* No. 136147, in the names of **E. F. W. Alexanderson** and **S. P. Nixdorff** (see RADIO REVIEW Abstract No. 485, July, 1920).

2497. **Gesellschaft für drahtlose Telegraphie.** High-frequency Alternators. (*British Patent* 148446, July 10th, 1920. Convention date January 19th, 1915. Patent not yet accepted.)

Relates to the subdivision of the stator windings into a number of groups connected in parallel.

2498. **Société Française pour l'Exploitation des procédés Thomson-Houston.** High-frequency Alternator. (*French Patent* 506859, December 2nd, 1919. Published August 31st, 1920.)

A high-frequency alternator for radio communication has a circular stator core from which is supported a pair of laminated rings, each carrying an armature winding arranged in slots. Stationary field magnet coils are also carried on the stator. A rotating inductor which is slotted to form a plurality of magnetic poles, the slots being filled with blocks of non-magnetic material such as copper, moves between the laminated rings carrying the armature winding. See also *British Patent* 13904/1915.

2499. **Compagnie Française pour l'Exploitation des procédés Thomson-Houston.** High-frequency Alternator. (*French Patent* 506981, April 10th, 1919. Published September 2nd, 1920.) Also **General Electric Co. (U.S.A.)** (*British Patent* 155061, September 26th, 1919. Patent accepted December 16th, 1920.)

The alternator is of the inductor type in which the inductor is constructed as a rotating

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disc, the edge of which carries magnetic members serving as bridge pieces. The disc is of non-magnetic material and carries radially disposed magnetic members around its outer periphery adjacent to the stator slots. The magnetic members are arranged to fill slots in the non-magnetic disc and are maintained in position by a metal band.

2500. **Gesellschaft für drahtlose Telegraphie.** High-frequency Alternators. (*British Patent* 147847, July 9th, 1920. Convention date January 19th, 1915. Patent not yet accepted.)

Relates to a H.F. alternator with sections of the armature winding connected in parallel so as to enable the insulation thickness to be reduced.

2501. **B. G. Lamme.** Data and Tests on 10,000 Cycles per Second Alternator. (*Electric Journal*, 28, pp. 110 and 132—136, April, 1921.)

An abridged reprint of a paper read before the American Institute of Electrical Engineers in 1904, describing one of the earliest practical H.F. alternators built by the Westinghouse Electric and Manufacturing Company for M. Leblanc. The design method used is closely similar to methods used to-day.

(E.) Static Frequency Raisers.

2502. **T. Minnohara.** The Use of the Impulsion Wave Method—Frequency Doublers. (*Revue Générale de l'Électricité*, 8, pp. 859—862, December 18th, 1920.)

A continuation of an earlier article by the same author in which mention was made of a special method of operating frequency doublers—there termed the impulsion wave method—in which the effective primary ampere turns are equal to the ampere turns of the direct current winding. The present contribution gives the full development of the saturation curve of the iron cores and a vectorial representation of the conditions of operation. The final section discusses the relation between output and volume of iron core.

2503. **J. F. Peters.** Static Frequency Doublers. (*Electric Journal*, 28, pp. 122—123, April, 1921. *Electrical World*, 77, p. 1382, June 11th, 1921—Abstract.)

An analysis of the mode of operation of transformer frequency doublers.

2504. **R. Swyngedauw.** Resonance of Third Harmonics in Transformers caused by Hysteresis and Saturation of the Iron. (*Revue Générale de l'Électricité*, 8, pp. 299—312, September 4th; pp. 363—373, September 18th, 1920.)

2505. **P. Trichard.** Continuous Wave Transmitter. (*French Patent* 506937, September 13th, 1918. Published September 1st, 1920. *British Patent* 154720, September 5th, 1919. Patent accepted December 6th, 1920.)

The specification describes a frequency multiplier in which two sets of three-electrode valves in parallel are employed. In each valve the grid is connected to the filament through a resistance. In order to multiply the frequency n times, $2n$ valves are used, the grids of which are excited by $2n$ potentials obtained by adding constant potentials furnished by accumulators to $2n$ alternating potentials forming two n-phase systems, the valves being assembled in parallel in two groups fed by two equal batteries of accumulators.

2506. **P. Mauv** and **V. Bontron.** On a Static Frequency Multiplier. (*Revue Générale de l'Électricité*, 9, pp. 523—527, April 16th; p. 2040, June 25th, 1921.)

Use is made of a three-electrode valve having a steady negative voltage upon its grid as well as the impressed A.C. voltage. The normal negative voltage of the grid is sufficient to reduce the plate current to zero, and the amplitude of the alternating current is adjusted so that the plate current flows for any desired fraction of the alternation. By combining together n such similar arrangements fed from an n phase supply, the initial frequency can be multiplied n times.

2507. **Gesellschaft für drahtlose Telegraphie.** Frequency Multiplying Apparatus. (*British Patent* 147441, July 7th, 1920. Convention date October 26th, 1918. Patent not yet accepted.)

Relates to transformer frequency raising apparatus having the primary and secondary circuits tuned to more than one multiple of the fundamental so that further frequency raising is accomplished by successive reflections between primary and secondary circuits on the lines of the Goldschmidt H.F. machine.

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2508. **P. Trichard.** Frequency Changers. (*British Patent* 160179, March 16th, 1921. Convention date March 16th, 1920. Patent not yet accepted.)

An arrangement for doubling the frequency of a single phase supply by the use of two thermionic valves in parallel, as indicated in Fig. 3, in which the input transformer-fed single phase supply is shown at T_1 and the output transformer at T_2. This may be connected to a second similar frequency doubling stage.

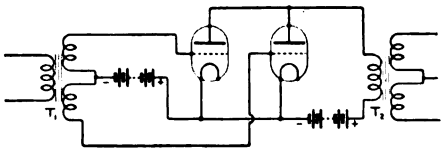

FIG. 3.

2509. **Gesellschaft für drahtlose Telegraphie.** Wireless Transmitting Apparatus. (*British Patent* 147702, July 8th, 1920. Convention date February 26th, 1914. Patent not yet accepted.)

Relates to choking apparatus inserted in the D.C. magnetisation circuit of static frequency multipliers.

2510. **Gesellschaft für drahtlose Telegraphie.** Static Frequency Transformers. (*British Patent*, 154885, October 26th, 1920. Convention date December 2nd, 1919. Patent not yet accepted.)

Relates to means for stabilising the static frequency raiser during keying.

2511. **P. Trichard.** Continuous Wave Transmitter. (*French Patent* 506295, September 9th, 1918. Published August 18th, 1920.)

The invention consists in a static frequency multiplier wherein to increase the frequency n times n thermionic three-electrode valves are employed. (See also RADIO REVIEW Abstract No. 2505 above.)

(F.) Thermionic Valves, and Valve Apparatus.

(2) GENERAL DESCRIPTIVE ARTICLES.

2512. **W. C. White.** The Vacuum Tube as an Engineering Problem. (*Scientific American*, 124, pp. 125, 138, February 12th, 1921.)

Discusses the need for more careful observation of the rating of a tube in connection with the work it is to perform—more on the lines of ordinary electrical machinery.

2513. **W. D. Owen.** Thermionic Amplifiers. (*Electrical Review*, 88, pp. 528—529, April 22nd, 1921.)

An abstract of lecture delivered before the North-Eastern Centre of the Institution of Electrical Engineers at Newcastle-on-Tyne on February 28th and giving a general description of the mode of operation of thermionic valves as amplifiers and oscillation generators.

2514. **E. F. Huth** and **S. Loewe.** Vacuum Tube Generator. (*German Patent* 310793, November 14th, 1917.)

A circuit in which the filament heating current is derived from the oscillatory current generated. An anode voltage source (V) only is used. (See Fig. 4.)

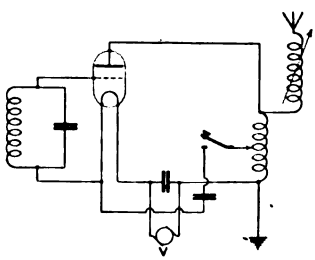

FIG. 4.

2515. **R. L. Smith-Rose.** The Evolution of the Thermionic Valve. (*Journal Télégraphique*, 45, pp. 41—46, March 25th; pp. 61—66, April 25th; pp. 81—86, May 25th, 1921.)

A translation of an article published in the *Journal of the Institution of Electrical Engineers*, April, 1918.

2516. **J. O. G. Cann.** The V24 Triode Valve. (*Q.S.T.*, 3, pp. 10—20, July, 1920.)

A short account of the chief properties of this valve.

2517. Thermionic Valves. (*Engineer*, 131, p. 610, June 10th, 1921.)

A summary of the chief points in the development of three-electrode valves.

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2518. **R. A. Heising** [Western Electric Company]. Thermionic Valve Apparatus. (*British Patent* 146519, July 5th, 1920. Convention date October 2nd, 1916. Patent not yet accepted.)

The negative potential for the grid of a valve is derived from a resistance in the grid circuit of another oscillating valve to avoid the use of a separate battery.

2519. **Compagnie Française pour l'Exploitation des procédés Thomson-Houston.** Valve Multiplier. (*French Patent* 508169, January 6th, 1920. Published October 4th, 1920.) Also **J. H. Payne** [British Thomson-Houston Co.]. (*British Patent* 148128, July 9th, 1920. Convention date January 3rd, 1919. Patent not yet accepted.)

A negative potential is maintained on the grid of a low-frequency thermionic amplifier or modulator by impressing on the grid circuit currents of radio-frequency derived from the grid leak of an oscillating valve.

2520. **W. C. White.** Some Operating Characteristics of Electron Tubes. (*Journal of the Franklin Institute*, 191, pp. 473—492, April, 1921. *Wireless Age*, 8, pp. 11—17, July, 1921. *Radio News*, 2, pp. 776—777 and 800—806, May, 1921. *Revue Générale de l'Électricité*, 9, p. 207D, June 25th, 1921—Abstract. *Science Abstracts*, 24B, p. 366, Abstract No. 758, July 30th, 1921—Abstract.)

The paper aims at furnishing practical information with regard to the use of vacuum tubes both for experimental and practical radio work and follows similar lines to that referred to in Abstract No. 1930, June, 1921. He discusses in somewhat greater detail the points there discussed. Aluminium lightning arresters for the protection of the H.T. machines supplying oscillating valves are described and illustrated. It is suggested that the operation of a radio telephone transmitter may very conveniently be watched by inserting a small tungsten filament lamp in the plate circuit of the modulator tube, the lamp being so chosen that normally it burns at a dull red. When the microphone is spoken to the lamp flashes up and thus indicates whether the modulation tube is operating correctly.

2521. **H. Gernsbach.** A Cold Cathode Vacuum Tube. (*Radio News*, 3, p. 93, August, 1921.)

A short note giving preliminary details about a new vacuum tube developed by **Dr. J. E. Lilienfeld** using a cold cathode which is stated to be suitable for use as detector, amplifier or oscillation generator.

2522. **J. Marsten.** Operation of Vacuum Tubes in Parallel. (*Radio News*, 3, p. 106, August, 1921.)

2523. **H. B. Sherman** and **S. R. Parker.** The Development of the Thermionic Valve and its Application to Telephony. (*Journal of the Engineering Institute of Canada*, 4, pp. 456—459, August, 1921.)

A general description of the valve and its use as a repeater.

(3) Theory and Physics of Thermionic Valves.

2524. **P. Heegner.** Theory of the Triode Oscillator with Intermediate Circuit. (*Archiv für Electrotechnik*, 9, pp. 127—152, August, 1920. *Electrical World*, 76, p. 937, November 6th, 1920—Abstract. *Science Abstracts*, 24B, p. 55, Abstract No. 112, January 31st, 1921—Abstract.)

A very thorough analytical investigation of the phenomena in a triode oscillator in which the oscillatory anode circuit is coupled with another oscillatory circuit. The effects of variations of capacity and inductance with different degrees of coupling are investigated and the technical application of the results obtained is discussed with the aid of numerical examples.

2525. **G. Stead.** Effect of Electron Emission on the Temperature of the Filament and Anode of a Thermionic Valve. (*Journal of the Institution of Electrical Engineers*, 59, pp. 427—432, April, 1921. *Electrical Review*, 88, p. 354, March 18th, 1921. *Nature*, 107, p. 216, April 14th, 1921—Abstract. *Technical Review*, 9, p. 128, May 24th, 1921—Abstract.)

Paper read before the Wireless Section of the Institution of Electrical Engineers; also discussion. See RADIO REVIEW, 2, pp. 170—171, April, 1921, for abstract of paper.

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2526. **H. Busch.** The Electric Heating of Wires in a Partial Vacuum. (*Annalen der Physik*, 64, pp. 401—450, March 10th, 1921. *Science Abstracts*, 24A, p. 356, Abstract No. 885, May 31st, 1921—Abstract.)

A very comprehensive experimental and theoretical investigation of the properties of wires heated electrically in hydrogen at various pressures. Iron and nickel wires were used as in the well-known ballast resistances.

2527. **B. van der Pol.** Amplitude of Free and Forced Triode Vibrations. (*Technical Review*, 9, p. 79, May 3rd, 1921—Abstract. *Radioélectricité*, 1, p. 115D, April, 1921—Abstract.)

See RADIO REVIEW, 1, pp. 701—710, November, 1920; and pp. 754—762, December, 1920.

2528. **B. S. Gossling** and **J. W. Hyde.** The Ionisation Potential of Helium. (*Radio Review*, 2, pp. 75—77, February, 1921. *Radioélectricité*, 1, p. 141D, June, 1921—Abstract.)

2529. **L. S. Palmer.** The Effect of Impurities on the Ionisation Potentials measured in Thermionic Valves. (*Radio Review*, 2, pp. 113—125, March, 1921. *Science Abstracts*, 24B, pp. 315—316, June 30th, 1921—Abstract.)

2530. **J. A. Fleming.** A Note on the Theory of the Thermionic Tube. (*Radio Review*, 2, pp. 133—136, March, 1921. *Science Abstracts*, 24B, p. 368, Abstract No. 762, July 30th, 1921—Abstract.)

2531. **M. v. Laue.** Equilibrium Conditions for Electron Emission from Glowing Bodies. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 199—218, September, 1920. *Science Abstracts*, 24A, p. 291, Abstract, No. 700, April 30th, 1921—Abstract. *Radioélectricité*, 1, p. 97D—99D, March, 1921—Abstract.)

A theoretical investigation of the conditions in the space charge both for parallel plates, one of which is the emitting body, and for the cylindrical case with an axial heated wire. The results show good agreement with Langmuir's measurements. On some points the article is a reply to criticisms made by **Schottky** on a previous paper by the author.

2532. **A. C. Bartlett.** Triode Valve Designs. (*Science Abstracts*, 24B, pp. 215—216, Abstract No. 439, April 30th, 1921—Abstract.)

See RADIO REVIEW, 1, p. 744, November, 1920.

2533. **T. C. Fry.** The Thermionic Current between Parallel Plane Electrodes; Velocities of Emission distributed according to Maxwell's Law. (*Physical Review*, 17, pp. 441—452, April, 1921. *Science Abstracts*, 24A, p. 445, Abstract No. 1145, June 30th, 1921—Abstract.)

The electrical equations applying to this problem are developed without neglecting the distribution of initial velocities. Maxwell's distribution of velocities is then considered in detail and the complete solution obtained. Curves from which to compute the space current are given for the cases when Maxwell's distribution applies; and curves are also included showing the deviation of the characteristic curves from the $\frac{3}{2}$-power law.

2534. **E. M. Sargent.** Conduction of Electricity through Vacuum and Gases with Applications to Design of Radio Apparatus. (*Radio News*, 2, pp. 694, 746 and 748, April; pp. 782 and 816, May, 1921.)

A general article on the theory of electronic conduction in valves.

2535. **K. Mühlbrett.** The Grid Current in Amplifier Valves. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, pp. 288—294, April, 1921. *Science Abstracts*, 24B, p. 367, Abstract No. 760, July 30th, 1921—Abstract. *Radioélectricité*, 2, p. 5D, July, 1921—Abstract.)

In valves containing an appreciable amount of gas, the grid current reverses for negative grid voltages due to ions passing to the grid. Between — 1 and — 4 volts the slope of the grid current curve may be negative, corresponding to a negative resistance to oscillations. This was confirmed by inserting an oscillatory circuit in the grid current; oscillations could be detected in a telephone receiver connected to the secondary of the transformer, the primary of which constituted the inductance of the oscillatory circuit.

2536. **G. Jaffé.** The Theory of the Vacuum Discharge. (*Annalen der Physik*, 64, pp. 733—744, April 29th, 1921.)

A theoretical discussion of the characteristics when the effect of remanent gas is taken into account.

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2537. **J. E. Lilienfeld.** The Theory of the Vacuum Discharge. (*Annalen der Physik*, 64, pp. 745—749, April 29th, 1921.)
A criticism of some of the conclusions drawn by **Jaffé**. See preceding Abstract.

2538. **F. Horton** and **Miss A. C. Davies.** Critical Electron Velocities for the Production of Luminosity in Atmospheric Neon. (*Philosophical Magazine*, 41, pp. 921—940, June, 1921.)

2539. **J. R. Carson.** The Equivalent Circuit of the Vacuum Tube Modulator. (*Proceedings of the Institute of Radio Engineers*, 9, pp. 243—249, June, 1921.)
If a voltage E_g is impressed between the grid and filament of a triode in the anode circuit of which is a load impedance z the operation of the device as a modulator may be correctly described by postulating an E.M.F. of value $M\left(\frac{\mu R_0}{R_0+z}E_g\right)^2$ impressed on the load impedance z through a resistance R_0 (internal resistance of tube). The modulator factor M is equal to $\frac{1}{2R_0}\frac{\partial R_0}{\partial E_a}$ where E_a is the anode voltage. μ is the voltage factor of the triode.

2540. **G. Holst** and **E. Oosterhuis.** The Electrical Conduction in Gases. (*Physica*, 1, pp. 78—87, June, 1921.)
Experiments on the conduction in argon and neon both with cold and with hot cathodes.

2541. **F. Trautwein.** The Thermionic Valve as a Measuring Instrument. (*Telegraphen- und Fernsprech-Technik*, 10, pp. 69—74, June, 1921.)
A continuation of a previous paper on the same subject. The present paper deals in the first place with the rectifying amplifier, in which the grid is made so negative that only the positive half waves produce the anode current, which is used to measure the P.D. applied to the grid. This is then extended to the use of multi-stage amplifiers for the measurement of small alternating voltages. The final section of the paper deals with the measurement of small alternating currents by superposing them upon the steady filament heating current of a diode or triode and measuring the charge produced in the saturation current. The galvanometer in the anode circuit is compensated for the steady anode current; several ways of doing this are described and test results are given showing the time required for the reading to get steady after altering the heating current. Various methods are discussed whereby the alternating current can be superposed upon the heating current and specially constructed two-electrode valves are recommended with high resistance filaments to increase the sensitiveness of the method.

2542. **E. Dubois.** On the Minimum Electric Discharge Potential in Hydrogen at Low Pressures. (*Comptes Rendus*, 173, pp. 224—225, July 25th, 1921; pp. 293—294, August 1st, 1921.)
Deals with some experimental investigations on discharge voltages and on the absorption of gas in the discharge tubes.

2543. **J. Marsten.** Characteristic Curves. (*Wireless Age*, 8, pp. 33—35, August, 1921.)
Discusses the various types of valve characteristics.

2544. **L. C. Pocock.** The Thermionic Tube—A Return to Simplicity. (*Electrician*, 87, pp. 232—234, August 19th, 1921.)
The writer points out that in most articles dealing with the theory of the thermionic valve complicated differential equations are evolved, the results of which are subsequently rendered useless by simplifying assumptions. Making the assumptions that (1) the grid current is zero; (2) the capacity currents are negligible, and (3) the grid voltage—plate current curve is linear, the author discusses in a simple way the following points: Amplification factor, effective amplification, the proportions of the circuit, dynamic characteristics, and the oscillating tube with vector diagrams.

2545. **E. V. Appleton** and **B. van der Pol.** On the Form of Free Triode Vibrations. (*Philosophical Magazine*, 52, pp. 201—220, August, 1921.)
An oscillographic investigation of the variations of the anode current in a self-excited triode valve. A method of estimating the amplitude of the anode current variations is given in terms of the oscillation characteristic and the circuit constants. The cooling of the

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valve due to the electronic emission is considered and its effect shown to be only marked at very low frequency of oscillations. For very high frequencies the emission is sensibly constant, so that the dynamic characteristic is generally but slightly different from the one deduced from a knowledge of the static characteristic and the circuit constants. The possibility is also considered of omitting the filament heating battery, the filament being maintained at the necessary working temperature by the effect of the emission current itself when once started.

2546. **Research Staff of the General Electric Company (London).** The Disappearance of Gas in the Electric Discharge—III. (*Philosophical Magazine*, 42, pp. 227—246, August, 1921.)

A continuation of previous work with the object of clearing up certain difficulties.* It is shown that the absorption of the gas is proportional to the ionisation.

2547. **A. W. Hull.** The Effect of a Uniform Magnetic Co-axial Cylinders. (*Physical Review*, 18, pp. 31—57, July, 1921.)

Equations of motion are developed for electrons starting from a cylindrical cathode and moving towards a co-axial cylindrical anode in a uniform magnetic field parallel to the common axis. The electrons will reach the anode if the ratio of potential difference to magnetic field is greater than the critical value and will fail to reach it if this ratio is less than this value. Formulæ are given expressing this critical value under different simplifying conditions as to the relative size of the two cylinders, and it is shown that when both cylinders are at the solution reduced to the familiar one of plain parallel plates the equation of the path of the electrons is deduced from the assumption that the space charge distribution is the same as without the magnetic field. Experimental curves taken under different conditions are in agreement with the theory within the limits of experimental error.

2548. **L. Page.** Theory of the Motion of Electrons between Co-axial Cylinders taking into account the Variation of Mass with Velocity. (*Physical Review*, 18, pp. 58—61, July, 1921.)

A continuation of theoretical work by A. W. Hull (see previous Abstract), and indicating an experimental method for verifying the theoretical formulæ.

(4) DESIGN AND CONSTRUCTION OF VALVES.

2549. **Société Gallot et Cie.** Valve Construction. (*French Patent* 498178, April 24th, 1918. Published December 31st, 1919.)

The invention has for its object an arrangement permitting the feeding of the incandescent cathode when the apparatus is in use by a two-core flexible cable in such a manner as to keep the cable away from other objects in the vicinity of the valve. The cable is put under tension by the means of a spring which is fixed at one end and at the other is attached to the shackle of a pulley over which the cable passes.

2550. **H. J. Round.** Thermionic Valves. (*British Patent* 154982, September 3rd, 1919. Patent accepted December 3rd, 1920. *Engineer*, 131, p. 85, January 21st, 1921—Abstract.)

To reduce the unevenness of the heating of the filament in a valve in which the emission current is of the same order as the filament current, a number of tappings are made to the filament and connected together through resistances to form the anode circuit connection.

2551. **B. S. Gossling** and **A. C. Bartlett** [General Electric Company, London]. Thermionic Valves. (*British Patent* 164175, March 19th, 1920. Patent accepted June 9th, 1921.)

A thermionic valve having cylindrical control electrodes situated at either extremity of the filament for the purpose of controlling saturation.

2552. **Le Matériel Téléphonique.** Valve Construction. (*French Patent* 504569, March 8th, 1918. Published July 8th, 1920.)

The specification describes more particularly a cathode for emitting electrons, the said cathode comprising a filament of platinum or similar metal coated with a coating formed of one part of a thermionically active substance, and one part of a noble metal such as platinum,

* RADIO REVIEW Abstract No. 1438, February, 1921.

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gold or silver. The coating can be formed of oxide of barium or oxide of strontium or of these two oxides mixed with oxide of calcium.

2553. **Société Française pour l'Exploitation des procédés Thomson Houston.** Valve Construction. (*French Patent* 504591, October 6th, 1919. Published July 8th, 1920.)
The invention relates to vacuum discharge devices and particularly to the construction of the electrodes. The cathode is in the form of a helical filament and the grid consists of a filament wound round the cathode. The anode is a cylinder surrounding the cathode and is supported by two arms, one on each side.

2554. **E. F. Huth.** Hot Cathode Tube. (*German Patent* 310132, April 18th, 1918. Patent granted November 14th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, p. 224, March, 1921—Abstract.)
A thermionic valve with grid and anode plates on opposite sides of the filament. The centre of the grid surface is made concave with respect to the filament.

2555. **E. H. F. Müller.** Vacuum Tube Relay. (*German Patent* 316363, July 27th, 1917.)
A valve of cylindrical design, the spiral grid of which may be rendered incandescent.

2556. **E. F. Huth** and **S. Loewe.** Vacuum Tubes for Relays, Amplifiers, etc. (*German Patent* 305665, March 21st, 1917. Patent granted October 4th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, p. 224, March, 1921—Abstract.)
A vacuum tube with a grid and an anode on opposite sides of a single filament. The grids and anodes are so arranged that if one anode current is increased the other is reduced in magnitude.

2557. **L. Guinet.** Vacuum Tube Construction. (*French Patent* 506944, December 26th, 1918. Published September 1st, 1920. *British Patent* 144305, June 3rd, 1920, Convention date December 26th, 1918. Patent not yet accepted.)
The grid and anode of a vacuum tube are in the form of plates of flat or curved shape, one on each side of the cathode. The plates may be corrugated or of "U" shape or the anode may be concave with respect to the grid.

2558. Modern Methods of Valve Manufacture. (See pp. 537—544 in this issue.)

2559. Vacuum Tube Construction. (*Wireless Age*, 7, p. 23, March, 1920.)
An illustrated abstract of a patent by **F. P. Driver** dealing with the means of supporting the electrodes of thermionic valves.

2560. **Société Anonyme pour l'Exploitation des procédés M. Leblanc-Vickers.** Electric Discharge Devices. (*British Patent* 161587, April 14th, 1921. Convention date April 15th, 1920. Patent not yet accepted.)
The grid of a thermionic valve containing mercury vapour or an inert gas such as argon consists of two or more parallel elements the openings in which are staggered relative to one another. The grids may all be maintained at the same potential or the ones nearer the anode may be at a lower potential than those nearer the cathode.

2561. **Western Electric Company, U.S.A.** Electric Discharge Apparatus. (*British Patent* 161619, November 28th, 1919. Patent accepted March 29th, 1921.)
Relates to a means for constructing the grid electrodes of thermionic valves.

2. Books.

MODERN HIGH SPEED INFLUENCE MACHINES: Their Principles, Construction and Applications to Radiography, Radiotelegraphy, Spark Photography, Electro-culture, Electrotherapeutics, High-tension Gas Ignition, The Testing of Materials, etc. By V. E. Johnson, M.A. (London: *E. and F. N. Spon, Ltd.* 1921. $8\frac{1}{2}'' \times 5\frac{1}{2}''$. Pp. viii + 278, with 93 illustrations. Price 14s. net.)
The subject with which this book deals is, as the author points out, one which has been almost completely neglected, and a treatise dealing with it is to be welcomed as a step towards the opening out of very great possibilities in machines for the direct generation of high pressure continuous current. We must confess however that the book leaves us with a sense of dis-

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appointment. It gives the result of many experiments which the author has carried out and describes many machines which he has constructed, but it gives little sign of any attempt to develop the machine along sound engineering lines or in accordance with the fundamental principles which underlie their design and operation. It is particularly to be regretted that no application has been made of the theory of the machines as given by Gray in his book on influence machines, which is referred to by the author and is obviously well known to him. Gray's book indicates very clearly certain sources of inefficiency which are necessarily present in the ordinary influence machine and which must be avoided if a really satisfactory one of high power is to be evolved, but the author has apparently made no attempt to apply these in practice. We would suggest also that before the design of these machines can be regarded as upon a footing in any way approaching that of a dynamo it will be necessary to discard the theory well-beloved by antiquated text-books and still adhered to by the author, in which unlike charges attract and like ones repel. It would, we fear, be very difficult to base the calculation of the magnetic circuit of a dynamo on the forces existing between imaginary north and south poles, and in the same way to really understand the action of an influence machine it is necessary to think of the electrostatic field between the various parts. The "like and unlike charge" theory is in fact quite capable of leading one astray, and in particular we would mention the theory of the action of the Wimshurst machine as given on page 41, which if examined quantitatively would show that the excitation of the machine would diminish instead of increasing. The true reason for increase of charge, viz. the edge effect between the earthed section and neighbouring ones has apparently been omitted.

The developments made by the author appear to be chiefly in the direction of increase of speed, a movement which is certainly along the right lines, as machines in the past have owing to their faulty mechanical construction been run at speeds much lower than the strength of the materials employed would allow. Further developments appear in the use of a triplex system of plates, in which one moving plate is influenced on both sides although this had been adopted by other workers previously. The use of grooved plates in order to increase the surface is a little difficult to follow and we certainly are surprised that the author has accepted without comment Wehrsen's claim to increase the capacity of a condenser by corrugating one of the coatings which is in effect what his corrugated sectors amount to. Apparently the reason for the increase in output with grooved plates is the difficulty in properly collecting the charge off a sectorless disc, and it is fairly clear that the material which is the ideal for an influence machine disc would be one having very good insulation along its surface in one direction while it would be conducting in a direction at right angles to it. The ordinary sectored disc is at best a poor substitute for this.

We believe that the suggested use of what may be termed "multipolar" designs of influence machine which is to be found in the book is novel and is one which will bear fruit particularly in machines of large size and comparatively low voltage such as might be used for wireless purposes, but we can scarcely agree with the development of machines with 10-foot discs which the author repeatedly advises. A little consideration of the centrifugal force acting on the discs and of the factors governing the output will show that if the machine is made two-polar the current output for a range of machines in which the centrifugal force at the edge of the discs is constant will be proportional to the 1·5th power of the radius of the disc while if the machine is made multipolar and all the machines are designed for the same voltage, the output will be proportional to the 2·5th power. It is rather unlikely that the weight and cost of the machine for really large sizes will vary at a rate less than the cube of the disc diameter, so that apparently an excessively large disc is not as the author suggests an economical use of material.

The weakest portion of the book is undoubtedly that dealing with numerical results, and here we must confess to a certain amount of scepticism. For example, the author claims to have produced a machine giving from 60 to 120 times the current of an equivalent Wimshurst with an increase in spark length, *i.e.* in voltage. The Wimshurst machine would, we believe, give a current of 15 to 20 microamperes at 100,000 to 120,000 volts, *i.e.* from 1·5 to 2·4 watts. Taking 2 watts as an average figure and taking a ratio of 100 to 1 as representing the author's claim to improvement, this gives an output of 200 watts from his machine. We note that he does not claim an efficiency of more than 45 per cent. nor do we think it possible with his arrangement so that the power input would be 445 watts or 0·605 h.p.

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In view of the fact that the machine in question is manually driven the improvement effected can hardly be as great as claimed unless the comparison has been made with a machine which is much below the ordinary standard. There are several other discrepancies which will be found if the figures are looked into closely. For example on page 188 we see that the current which should have been 1·5 to 2 milliamps would not move the needle of the milli-ammeter, and is estimated by the author as less than 0·1 milliamps.

Again an illustration is given of a ¼ h.p. electrostatic motor, but we are unable to trace any evidence that it ever gave this power, nor do we think it at all possible, as it clearly states that the generator gave more current than the motor could absorb. Allowing 50 per cent. for motor efficiency and 45 per cent. for the generator we obtain the same impossible figure for the author's output of horse power.

We note again on page 209, that Q the quantity of electricity is given in Joules, which of course is incorrect, but sufficient has been said of the book's deficiencies. On its behalf we would say that it is suggestive and that the author has clearly made a very careful study of all that has been done on the subject, and on this account alone it deserves the attention of any one interested in this important but hitherto neglected branch of applied electricity.

E. A. WATSON.

THE ELECTRICAL TRANSMISSION OF PHOTOGRAPHS. By Marcus J. Martin. (London: *Sir Isaac Pitman & Sons, Ltd.* 1921. Pp. xi + 136. 7″ × 4½″. Price 6*s.* net.)

This book has been written as an attempt to condense into a useful and concise tome a description of the methods of transmission of photographs by electricity, their progress and application. A portion of the subject-matter appeared in series form in the *Model Engineer and Electrician* and these enlarged and with an historical introduction form the basis of the work.

Starting with an interesting description of the early history and experiments, the author describes the various known methods which have been employed culminating in the invention and development by Professor Kom of the selenium operated machine, followed by the later-known developments of the telautograph, telestereograph, telectrograph, etc. The difficulties and shortcomings as well as the accomplishments of these methods of transmission are well and ably dealt with.

Television has a chapter to itself, several methods of presenting an actual instantaneous visual impression of the distant object are described, the greatest obstacle and defect of all known methods being the human visual defect of persistence of vision.

Wireless transmission has only five pages allotted to it, the author having dealt fully with this portion of the subject in his book on "The Wireless Transmission of Photographs." •

The author has had a considerable experimental and practical experience on his subject and in order to assist those who desire to experiment themselves, a chapter has been included containing full working drawings and descriptions of apparatus similar to that used by the author himself in his investigations.

There might have been included a few modern examples of telegraphed photographs, but apart from this the book is well and fully illustrated.

E. A. GORDON.

ELECTRICITY AT HIGH PRESSURES AND FREQUENCIES. By H. L. Transtrom. (Chicago: *The Joseph G. Branch Publishing Co.* Second Edition. 1921. Pp. xi + 247. 7½″ × 5″. With 141 Illustrations. Price $2.50.)

The book is ostensibly written to bring to the notice of practical electrical workers the wonders of high frequency high voltage electrical phenomena in a not too technical manner. Actually it would seem to be a book best suited for the experimenter, in spite of the author's brief discourse (in the preface) on the trend of modern practice in high voltage power transmission lines.

The first 164 pages in the book are devoted to general electrical principles and to explanations of the mode of operation of dynamos, transformers, etc., while the remainder treats purely of the effects and phenomena exhibited by high frequency currents obtained from the so-called "Tesla" coils. Many spectacular experiments with these currents are described and

• "The Wireless Transmission of Photographs." (The Wireless Press, Ltd.)

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illustrated, and what is more important for the experimenter, data is given in most cases of the actual construction of the coils, condensers, etc., that may be employed. The reader is thus enabled (if he so desires) to reconstruct the apparatus and to repeat the experiments.

P. R. C.

THE YEAR BOOK OF WIRELESS TELEGRAPHY AND TELEPHONY, 1921. (London: *The Wireless Press, Ltd.* 1921. Pp. lxxxiv + 1355. 8″ × 5″. Price 21s. net.)

The 1921 issue of the Year Book maintains the level of interest and usefulness, to the wireless man, reached by preceding editions.

The volume begins with a calendar section containing, on the pages devoted to 1921, many date references to outstanding scientific discoveries—most interesting reminders of the pioneer work done by the early enthusiasts. A few lines of postal information added to this section would prove useful (although possibly it is considered that the changes of rates are too frequent nowadays to justify it !). Four pages of "Official Holidays" serve to remind the wireless man that if he is not on holiday, others are, and yet others recovering therefrom.

An interesting section of twenty pages is that devoted to a "Record of the Development of Wireless." One looks in vain, however, for the name of Lodge in these pages. Surely Lodge's early recognition of, and insistence on, the necessity for tuning should appear here under date. The reader must turn to p. 1149 where, in Professor Howe's article, he will find full justice done to the work of this pioneer. Under 1879 we find Hughes' discovery of coherer action mentioned, but it is of interest to remember also that Hughes, by his experiments over 500 yards' distance, really demonstrated the existence of electric waves, although the meaning of his results was not at that time appreciated. Should not the date of the discovery of the "Edison effect" find a place ? Also the date of the addition of the "grid" by De Forest, as fixing the genesis of the triode ?

A large section of the book is that devoted to International Laws and Regulations. The texts of the International Radiotelegraphic Convention, and of the Convention on Safety of Life at Sea are followed by the wireless laws and regulations of all countries of the world, arranged in alphabetical order, from Abyssinia to Zanzibar. Not the least useful feature of this section is the inclusion of maps showing the location of wireless stations, and brief descriptions of the country concerned.

The Directory of the World's Wireless Stations, which forms the next section, and one of the most useful, has been enlarged by the addition of about 30 per cent. to the list of call letters of land and ship stations.

The article on "Radio Communication and Meteorology," by Lieut.-Colonel E. Gold, is repeated from the previous edition, with slight additions, as also is the article on "Wireless and Time," by the Secretary of the Royal Geographical Society, Mr. A. R. Hinks.

The section on "International Time and Weather Signals" has been extended. One notes that the circular clock diagrams of the Paris signals have been replaced by clearer straight-line diagrams, but errors have crept in here. The number of dashes between 1044 and 1045 should be nineteen, not eighteen. Similarly there are fourteen "d's," not thirteen, between 1046 and 1047.

The section entitled "National Résumés," being a series of short articles by well-known writers on the progress of wireless in various countries, contains much of interest.

A series of four special articles follows. Mr. P. R. Coursey writes on the Interference Problem, Mr. Stuart Ballantine on the Radio Compass, Professor Howe on "Historical Landmarks in Wireless Invention," and Mr. F. P. Swann on "Valve Amplifiers for Shipboard Use," the last article describing the use of a four-electrode valve. All these articles are worth study. Reference to Professor Howe's article, in which justice is done to Lodge's early work, has already been made.

The Patent Section by Mr. J. Shoenberg is a very useful section for reference, and is complete with name and subject indexes of 1920 patents, both British and American.

The Aviation Section by Lieut.-Colonel H. B. T. Childs has been enlarged, further data on aviation stations, marking of aircraft, etc., having been added.

The "Useful Data" Section comes next, and has been slightly enlarged. Regarding the list of definitions, although it is true that there may be (as found by Kipling's Neolithic Poet, in the case of tribal lays) "nine-and-sixty ways" of constructing a definition, yet one feels that some of those given here could hardly be included. For instance, "Ampere turn" is

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defined as the unit of mmf without any reference to 4π. (Not that any one wants 4π in it, but things go wrong if you calculate without!) Then again, "Self-inductance of a circuit" is defined as "*that portion* of the inductance . . ." But why "that portion"? Surely "inductance" and "self-inductance" are always regarded as synonymous terms. Further the definition of "inductance" clearly refers to self-linkage only. "Natural frequency" is defined as that "with which a circuit will oscillate when supplied with energy and left to itself." While this is true for "lumped" inductance and capacity, it should be made clear that it does not apply to such a circuit as an open solenoid, which has many natural frequencies at which it will oscillate if supplied with a suitable distribution of energy, and left to itself. The definition of "Mutual inductance" as energy seems hardly to convey as clear an idea—especially to the beginner—as by employing the conception of linkage of magnetic lines with the electric circuit.

On p. 1250 are given data on "Distance of Horizon at Sea." Although the figures at the bottom of the page are approximate, one notes that they are given to an accuracy of one part in thousands and, curiously enough, nearly all differ by about 8 per cent. from the theoretical figure given by the formula above. Possibly atmospheric refraction (in reading the slide rule) accounts for the discrepancy.

In the list of "Conventional Signs used in Wireless Diagrams," the battery polarity shown is unconventional. See correct polarity in diagrams (1) and (2) on preceding page. In circuit (2) should not "r" instead of "R" appear in the final formula?

A few pages are devoted to a list of companies engaged in the commercial development of wireless, and are followed by a Biographical and Obituary Notice Section which affords personal touches which are invariably of interest.

There is a very useful list of Wireless Literature, including books and articles on the subject arranged in alphabetical order. Under "Periodicals" on p. 1327 one misses the *Proceedings of the I.E.E.* which contains accounts of the activities of the Wireless Section. The corresponding American journal is mentioned.

The Amateur Section consists of a short article by Mr. E. Blake giving an account of amateur activity during 1920, and a directory of wireless societies. Considering the importance of the amateur to the progress of wireless (as well expressed on p. 1129 of the 1920 Year Book), the size of the section devoted to his activities seems rather small, although it must be recollected that other sections of the book appeal to the amateur, as well as to those engaged professionally. It is of great importance that the amateur movement should not be hampered by restrictive legislation, and it is to be hoped that the present law requiring every receiving apparatus to be licensed will be abolished, if only for the reason that illicit receiving with modern apparatus cannot be detected when no external aerial is used.

Regarding the word "amateurism," one rather wishes for a more pleasing word to express the same idea.

The volume concludes with a list of Wireless Telegraphy Courses in Colleges and Schools, and a Code Section giving the Morse signs.

There is a good alphabetical index at the beginning of the book.

R. C. CLINKER.

LONGUEURS D'ONDE ET PROPAGATION. By P. Viellard, with a Preface by General Ferrié. (Paris: *Gauthier-Villars et Cie.* 1921. 10" × 6½". Pp. xii + 416. Price 55 frs.)

The scope of this book is indicated by the sub-title "Étude théorique de la T.S.F. extérieure," that is to say, it deals with the mathematical theory of that part of the subject which is external to the four walls of the station. General Ferrié has written a brief preface outlining the need for and the scope of the work. The book is divided into two parts of which the first deals with the oscillations produced in the aerial and the length of the wave produced, whilst the second deals with the propagation of the waves over the earth's surface, their attenuation due to various causes and their effect on the receiving aerial. A chapter is devoted to aeroplane aerials and another to the losses occurring in the masts and the reradiation of energy from the masts.

The author assumes a considerable knowledge of mathematics and of electromagnetic theory. The subject is approached from the point of view of the mathematical physicist rather than that of the electrical engineer, but it is that of a mathematical physicist who is

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thoroughly conversant with the practical details of radiotelegraphy. At many points throughout the book one is given actual measured results to compare with the values obtained by theory and at the end of Part II. is a chapter giving a *résumé* of the principal results arrived at and their application to the calculations necessary in planning and designing a radiotelegraphic station.

Although the names of previous workers in the subject are sometimes mentioned, there is hardly a reference to enable one to look up any previous publication. This is undoubtedly a serious defect in a book of this advanced specialist type. The volume forms, however, a useful addition to the literature of the subject and will be specially welcomed by those who, already having some knowledge of the subject, wish to make a special study of the theory of the aerial.

G. W. O. H.

Die neuere Entwicklung der Funkentelegraphie; ein Siegeszug der Vakuumröhre. By H. Wigge. (*Cöthen. Anhalt, "Ingenieur Zeitung."* Second Edition. 9″ × 6″. Pp. 71. Price not stated.)

This is a semi-popular description of the action of the thermionic valve and its manifold applications. It contains hardly a single mathematical symbol, but diagrams of connections are given of almost every known way of using the valve for detecting amplifying and generating oscillations. A section is devoted to the practical application of the triode to various branches of radiotelegraphy and a section to radiotelephony. The book concludes with a useful classified bibliography of the subject. The descriptions are simple and clear, the diagrams are fairly good, but the photographic reproductions are as poor as any we have ever seen.

G. W. O. H.

Einfuhrung in die Elektrotechnik. By Otto Nairz. (Leipzig: *J. A. Battle.* 10″ × 6½″. Pp. viii + 415, with 351 figures. Price unbound 18M., bound 25.20M.)

This introduction to electrotechnics is based upon lectures delivered at Charlottenburg by Professor Slaby, one of the founders of the Telefunken Company. It assumes no previous knowledge of the subject and is a very suitable text-book for those beginning the study of electrical engineering. It covers the underlying principles of the whole subject both continuous and alternating. The last of the sixteen chapters is dovoted to high-frequency currents and wireless telegraphy. In view of the origin of the book it is not surprising that this chapter occupies more than a sixth of the whole volume. It is largely obsolete, however, the detectors described being the coherer, the magnetic, electrolytic, etc., no mention being made of the thermionic valve. This is partly explained by the fact that the preface is dated 1913; no attempt has been made to bring the book up to date.

G. W. O. H.

Books Received.

Les Tubes a Vide. By P. Dapsence. (Paris: *G. Pericaud.* Second Edition, 1921. Pp. 49. 8¼″ × 5¼″. Price frs. 2.50.)

Radiotelefonia. By D. Ravalico. (Torino-Genova: *S. Lattes & C.* 1920. Pp. vii. + 219. 6¼″ × 4¼″. Price L.14.)

La T.S.F. par les Tubes a Vide. By P. Louis. (Paris: *Librairie Vuibert.* 1920. Pp. 142. 9″ × 5¾″. Price frs. 6.)

Le Livre de l'Amateur de T.S.F. By J. Roussel. (Paris: *Librairie Vuibert.* 1921. Pp. vi + 304. 10″ × 6½″. Price not stated.)

Correspondence.

WIRELESS APPARATUS.

To the Editor of the "Radio Review."

Sir,—With reference to the restrictions hitherto in force on the manufacture, purchase, sale and possession of wireless apparatus, I am directed by the Postmaster-General to say that,

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in consequence of the lapse of Regulation 22 of the Defence of the Realm Regulations so far as Great Britain is concerned, such apparatus may now be made (or bought, sold or held) in Great Britain (but not in Ireland) without permit or restriction.

The supervision by the Post Office of dealings in such apparatus has accordingly ceased so far as Great Britain is concerned. As indicated above, Regulation 22 is still in force as regards Ireland.

I am to add that the Postmaster-General's licence under the Wireless Telegraphy Act, 1904, is still necessary before any apparatus for wireless telegraphy may be installed or worked. An arrangement has, however, been adopted for allowing "toy" sets of wireless apparatus to be used (in Great Britain only for the present) without formal licence provided that the designs of the sets have been approved by the Postmaster-General and that the sets have been stamped or marked to that effect before sale. Firms or persons who desire to sell "toy" sets of apparatus for use under this arrangement should furnish full particulars (including illustrations or diagrams) of the apparatus, in order that the question of approving the designs of the sets may be considered. Where the designs appear suitable, it will be necessary to require that specimen sets shall be submitted for inspection before definite approval is given. Generally speaking, a "toy" set will be regarded as apparatus arranged for transmission and reception as a Hertzian oscillator, and not intended for connection to earth or to any aerial other than small rods with or without vanes. The range of such sets should not exceed 50 yards.

J. I. DEWARDT,
for the Secretary.

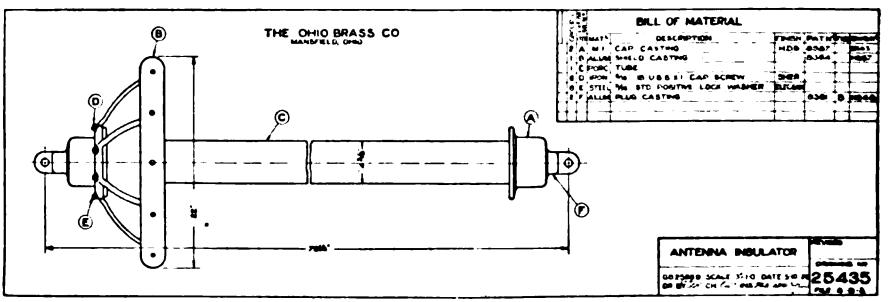
General Post Office,
London.
September 1st, 1921.

A NEW DESIGN OF AERIAL INSULATOR.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—I notice in the RADIO REVIEW for April an article on a new design for aerial insulators. I am surprised that the original investigators of this type of insulator were not mentioned by Messrs. Elwell and Bullers.

I am enclosing herewith blueprint No. 25435 of the Ohio Brass Company, Mansfield, Ohio. This is the insulator shown on your page 198, and is the exact insulator produced by Mr. Elwell



Reproduction of the blueprint referred to in Mr. Sawyer's letter.

for the British Post Office stations at Oxford and Cairo. The gentleman who did most of the original research work on these insulators either is now or has been connected with the Ohio Brass Co., and Mr. Edward Austin, Mr. Leonard Fuller and Mr. W. A. Hildebrand did most of the research work which was carried on at Barberton, Ohio, at the expense of the U.S. Navy Department.

E. W. SAWYER.

New York,
June, 1921.

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Editor:
PROFESSOR G. W. O. HOWE, D.Sc., M.I.E.E.
Assistant Editor:
PHILIP R. COURSEY, B.Sc., F.Inst.P., A.M.I.E.E.

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THE

RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

Editor: Prof. G. W. O. HOWE, D.Sc., M.I.E.E. Asst. Editor: PHILIP R. COURSEY, B.Sc., A.M.I.E.E.

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INFORMATION FOR CONTRIBUTORS

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RADIO REVIEW

VOL. II NOVEMBER, 1921 NO. 11

Editorial.

Poulsen Arcs with Shunt Condensers.—Professor P. O. Pedersen has published a paper in the *Proceedings of the Institute of Radio Engineers* for June under the somewhat misleading title of "On the Poulsen Arc in Coupled Circuits." In this paper he does not deal with coupled circuits in general, but only with one special circuit arrangement which one might hesitate to refer to as a coupled circuit. It is none the less a very important arrangement because it has been used in a number of the large arc transmitting stations. In these stations it is customary to insert the arc between the antenna and the earth, so that the antenna and its loading coil constitute the oscillatory circuit across the arc without any intermediate closed oscillatory circuit. To avoid a short-circuit of the direct current in case any part of the aerial is accidentally earthed it is customary to insert a large series condenser in the earth connection. Now it has been found that a condenser connected as a shunt either across the arc or across the arc and the series condenser gives an increased output. It might be suspected that the increased antenna current was due to harmonics but it is claimed that this is not so, and that the signals are actually strengthened by this arrangement. Professor Pedersen compared the measured values of the currents in the arc, antenna, and shunt circuit with those calculated on the assumption that the arc acted as a simple source of alternating current of a single frequency. Considerable differences were found and Professor Pedersen shows that these are due to the fact that the shunt and series condensers and the arc form an oscillatory circuit of high frequency which is set oscillating every time the arc strikes and that this oscillatory current is superimposed upon the normal arc current causing the arc to be wholly or partially extinguished once or twice at the beginning of the cycle. Professor Pedersen points out that although the antenna current for a given arc current may be increased, it necessitates a higher supply voltage for the arc and it increases the wavelength. The increased efficiency will be due to some extent to the latter effect. He states that the increased efficiency was only obtained at the cost of steadiness and that in his opinion the advantages gained by the device are not of any great value. It would be of interest to learn whether in any practical case an increased efficiency or output has been obtained by the use of a shunt condenser without sacrificing steadiness or purity of the emitted wave. [3728]

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The Action of the Grid Leak in the Audion Detector.*

By Professor G. W. O. HOWE, D.Sc., M.I.E.E.

There is much haziness in many of the descriptions given in text-books and articles of the action of the grid condenser and grid leak when a triode is used for reception in the manner originally introduced by de Forest and often referred to as the audion method of reception. Fig. 1 shows the connections under consideration with the source of high-frequency signals represented by an alternator in the grid circuit. In Fig. 2 the curve represents the grid characteristic, that is, the current flowing in the grid circuit plotted against the P.D. between the grid and the negative terminal of the filament. The line OL is drawn at an angle θ to the vertical such that the tangent of this angle is equal to the leak resistance R. This line cuts the curve at P.

When no alternating E.M.F. acts in the grid circuit, the grid assumes the steady negative potential OA and the current AP flows from filament to grid through the external circuit. Since the tangent of the angle θ between the line OL and the vertical is equal to the value R of the grid leak, OA represents the P.D. across the grid leak and AP the current through it.

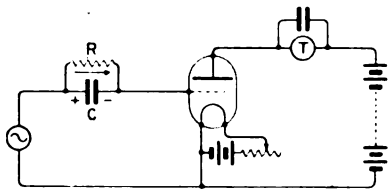

FIG. 1.

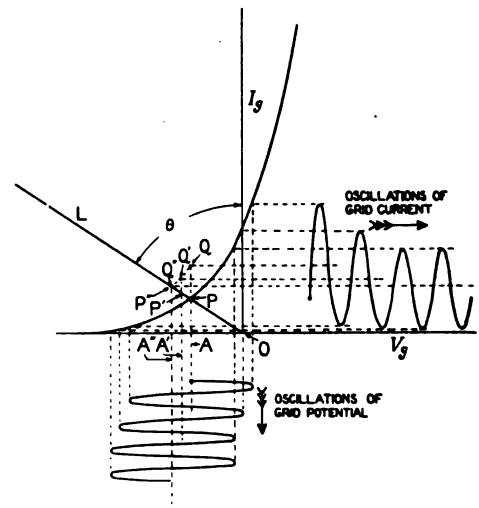

FIG. 2.

If now an alternating E.M.F. be introduced into the grid circuit, the grid potential begins to oscillate symmetrically on either side of the point A, but because of the curvature of the characteristic the mean grid current is increased to AQ. Since the mean P.D. across R is still OA, the mean current through R is still AP, hence the difference PQ must pass into the condenser, increasing its P.D. from OA say to OA'. This causes the mean current through the leak to increase to A'P'. The next oscillation of grid potential takes place about A' instead of A and the grid current reaches a lower maximum, and

* Received for publication February 17th, 1921.

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has a lower mean value, say Q'. The difference between A'Q' and A'P' must pass into the condenser and increase its P.D. say to A". This will cause the mean current through the leak to increase still further to A"P"; it will also cause the succeeding oscillation of grid potential to move over a lower part of the curve and thus lower the mean grid current to Q". This goes on until the curve QQ'Q" meets the line OL, that is, until the decreasing mean grid current equals the increasing mean leak current; when this point is reached the condenser gets no further charge. The increased negative potential of the grid causes a fall in the anode current which affects the diaphragm of the telephone receiver.

It is seen that when a signal is being received, although the grid potential becomes more negative, the mean grid current as read on a milli-ammeter inserted in the grid circuit is increased, viz., from AP to A"Q" in Fig. 2.

The effect of the signal on the anode current depends on the steepness and curvature of the anode current characteristic which we have not shown. There are two separate effects, one due to the displacement of the mean grid potential from A to A" causing a fall of anode current and the other due to the oscillation of grid potential causing a certain amount of rectification of the anode current depending on the curvature of the anode current characteristic. On the upper bend these effects are in the same direction but on the lower bend they are in opposition.

Note on a Four-electrode Thermionic Vacuum Tube.*

By H. J. VAN DER BIJL, M.A., Ph.D.

In a recent issue of the Radio Review † an article appeared by Professor Fleming on what he calls "A Four-electrode Thermionic Detector for Damped and Undamped Electric Oscillations of High or Low Frequency." As was pointed out in the editorial notes of the same issue, this type of tube originated with Majorana in 1912. In 1914 I made investigations on this type of tube, and while I did not find it to be as satisfactory a detector as the audion, which had at that time already been well developed, Fleming's publication has revived a certain amount of interest in this tube, especially his suggestion to use it as an A.C. ammeter and for the purpose of indicating small differences of potential in A.C. bridges. It may therefore not be out of place to give a brief discussion on a few points regarding the operation of this type of tube, which are apparently not well known.

Fleming states that "the peculiar property of this thermionic detector is that if a small difference of potential whether of high or low frequency is set up between the potential plates the thermionic current passing between the filament and the collecting plates at once falls to an extent determined by this potential difference." This effect, which was also observed by Majorana,

* Received July 25th, 1921.

† Radio Review, 2, p. 38, January, 1921.

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is to be expected. It is well known that in an audion the control electrode need not have the form of a grid placed between the filament and the anode, although this is usually the preferred form, but could be a plate or wire placed anywhere in the neighbourhood of the filament. Consequently, two control electrodes placed symmetrically with respect to the filament and anode, as in the tube shown by Fleming, would have equal effects on the emission current. The result is that when the tube is connected in a circuit in such a way that the one control electrode becomes as much positive as the other one becomes simultaneously negative, the resultant effect on the current to the anode would be *nil*, if there were no other influences. What actually happens, however, is that when one control electrode, say P_1, becomes positive, it attracts electrons and therefore acquires a negative charge. During the following half cycle the other control electrode, P_2, attracts electrons. The result is that both electrodes acquire a negative charge and this causes the reduction in the electron current to the anode which has been observed. But with the circuit shown by Fleming the electrons, having once entered the control electrodes P_1 and P_2, have no way of escaping from the system comprising these electrodes and the input circuit connected to them (assuming the vacuum and insulation to be perfect).

Fleming states that he had not yet determined the effect of a slight reduction in the vacuum. The effect of gas on the behaviour of this type of tube is known. If the vacuum in the tube and the insulation between the terminals were perfect and the air dry, this tube would become inoperative as a radio detector, for the reason that since the negative charge accumulating on the control electrodes cannot leak away, the anode current cannot return to its normal value on the cessation of a train of incoming oscillations. The case is very similar to that of an audion operating with a blocking condenser in the grid circuit. Unless there is collision ionisation in the audion or the blocking condenser is leaky or is bridged with a high resistance, to enable the negative charge accumulating on the grid gradually to leak off, the tube becomes inoperative. If the tube contained a small amount of gas the positive ions formed by collision ionisation would neutralise the negative charge on the control electrodes, as is well known to be the case with an audion containing a small amount of gas and operating with a blocking condenser in the grid circuit. Of course, when oscillations are impressed on the input circuit, the rate of accumulation of negative charge must at first exceed the rate of neutralisation, but this latter rate must be sufficiently large to enable the control electrodes to discharge themselves between successive trains of oscillations.

But it is not possible to rely on the presence of gas when the tube is to be used for quantitative measurements, because it is extremely difficult to keep the pressure of a small amount of gas in the tube constant, and unless this is done, the rate of formation of positive ions and therefore also the rate of neutralisation of the negative charge on the control electrodes would not be constant, thus making the reduction in the anode current erratic.

The best way is to provide for the neutralisation of the negative charge on the control electrodes. This can be done by using an inert vapour in the tube in thermal equilibrium with the parent substance, for example, mercury,

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which is kept at a constant temperature. This would insure constant pressure of the vapour and therefore consistent behaviour of the tube. Or again, the neutralisation can be provided for by connecting a suitable point of the input circuit through a high resistance to the filament, the circuit being so arranged that the two control electrodes assume under the influence of the impressed oscillations, equal and opposite potentials with respect to the filament.

The similarity between the four-electrode tube and the audion operating with a blocking condenser in the grid circuit will be apparent. But there are certain differences which are interesting, although perhaps not of great importance. In the audion the accumulation of negative charge on the grid takes place during alternate half periods, while in the four-electrode tube this happens every half period. In the audion the anode current fluctuates with a frequency equal to that of the impressed oscillations, the mean value of the anode current being lower than the steady D.C. value. In the four-electrode tube the anode current also fluctuates, although not as much as in the audion, but the fluctuations have a fundamental frequency twice that of the impressed oscillations, and, provided that the control electrodes be made as effective as the grid in the audion, the reduction in the anode current would be somewhat greater. This is due to the counteracting effect of the two control electrodes as far as the direct action on the anode current of the potentials impressed on them is concerned. If the four-electrode tube has any advantage over the audion in this respect it is doubtful if it would be sufficiently great to warrant the complication of a fourth electrode. It may be well to point out that the operation of the audion with a condenser in the grid circuit is improved by operating the audion, as is now frequently done, with the grid maintained at a steady positive potential with respect to the filament, of such value as to operate on that part of the grid-current—grid-potential characteristic where the curvature is greatest, and with the anode potential and filament current so adjusted as to operate on the upper part of the anode-current—grid-potential characteristic where it becomes concave towards the voltage axis. The necessary steady positive potential on the grid can be maintained simply by connecting the input circuit to the positive end of the filament.

As regards the using of vacuum tubes for measuring small potential differences in A.C. bridges, I presume it is known that the audion has been used successfully for such purposes. (See, for example, Fig. 109 on p. 213 of my book on "The Thermionic Vacuum Tube." *) Whether or not the four-electrode tube would work better than, or even as well as the audion in such circuits is something which has yet to be established. In any case, it is risky to have floating electrodes, that is, electrodes whose potentials cannot definitely be controlled, in a vacuum tube, and unless provision is made for neutralising, whenever necessary, the negative charge accumulating on the control electrodes, the four-electrode tube could hardly be relied upon as a measuring instrument.

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* H. J. van der Bijl. "The Thermionic Vacuum Tube." (New York: *McGraw-Hill Book Co., Inc.* London: *McGraw-Hill Publishing Co., Ltd.* 1921.)

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Radiotelegraphy in the Dutch East Indies.

The August number of the organ of the Dutch Colonial Defence Society,* which Society has been established "to promote by all means at its disposal, every measure that will strengthen the economic and military position of the Dutch Indies," is devoted to a historical review of the development of radiotelegraphic communication between the Dutch Indies and Holland and an account of the present position. It is a very important document both from the political and technical points of view and we feel sure that the following abstracts from it will prove of interest to our readers :—

"It is the object of the present essay to make widely known the grand work performed by the officials and engineers of the Dutch East Indian Postal, Telegraphic and Telephonic Service. The Dutch nation has reason to be proud of these men, who, sure of future success, carried through their plans in spite of a thwarting bureaucracy and of administrative pettiness. The Indië Weerbaar Society cannot think of a better way to honour Mr. Pop, Dr. de Groot and their collaborators, than by devoting a special number of its organ to the work they have achieved and spreading it broadcast all over the world."

Plans for a wireless chain have existed for many years. The van der Bilt scheme worked out in conjunction with the Marconi Company proposed intermediate stations in Tripoli, Italian Somaliland and Ceylon, but it was hoped later to do without the last named and thus be entirely free from British control and have their means of radio-communication in the hands of countries belonging to a different group to Britain who controlled the cables. The action of Italy in the war proved "how vain it is to count on political constellations for projects of this kind." The war made the carrying out of the van der Bilt—Marconi scheme impossible and also proved that strategically it would have been an absolute failure.

Another rival scheme known as the Moens scheme was coupled with the Telefunken Company, the proposed route being Nauen—Sayville—Curaçao —German South Seas—Java. This scheme did not survive its rival.

Careful experiments were made during 1913 and 1914 at several experimental stations in the East Indies, the results of which led Dr. de Groot who was in charge at Situbondo to propound his theory that night transmission was relatively easy between points separated by multiples of 3,000 km, a very promising theory, seeing that the distance to Holland was 12,000 km.

Since that time de Groot's energies have been concentrated on the attainment of direct communication between the Indies and the Motherland. His theory received some support from the fact that de Haas received signals at night from Nauen, a distance of 9,000 km, with a contact detector without amplifiers, the antenna power being 100 kW and the wavelength 5 km. In December 1916 de Groot returned from Europe and America with new receiving apparatus and reception from the large European stations was

* *Orgaan van de Vereeniging "Indië Weerbaar,"* 4, pp. 4–44, August, 1921.

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obtained with fair regularity. They were spurred on to these developments by the fear which proved only too well founded, that the Allies would impose a telegraphic blockade.

"Meanwhile it was clear that reliable means of communication especially in war time must take years to construct owing to the large power-plant required and that it could therefore be of little use during the war. This led to the thought of temporary communication by way of neutral intermediate stations, *e.g.* Honolulu and neutral America, whence it was so much easier to communicate with Holland than from Java. The preliminaries had been arranged by Dr. de Groot during his journey through America with the

Location of the Station.

naval authorities. When, however, shortly afterwards, before the arrival of the American transmitter, it was proved by the reception tests, with how little energy, comparatively speaking, the distance between Holland and Java could be spanned at night time, *provided short waves were used*, the colonial authorities changed their minds and chose Holland instead of America for their object, the more so as uninterrupted communication with America had meanwhile been obtained in another way.

"The American transmitter arrived here in August, 1917. . . . During the period between the ordering and the receiving of the transmitter, the balloon idea was abandoned as a more felicitous mastless solution had been found in the shape of an aerial across a mountain gorge, consisting of an aerial

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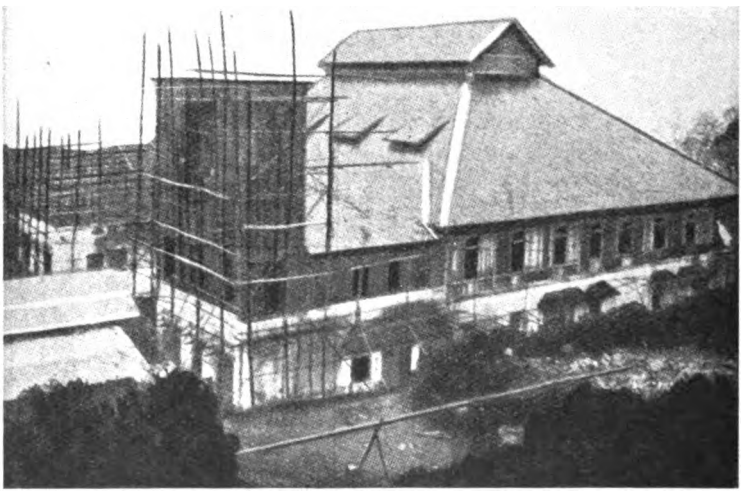
suspended from steel hawsers connecting the mountain tops around the gorge, the station being at the bottom. . . . It afterwards proved itself superior to the highest mast aerial.

"A suitable gorge was found 9 km from the main road with steep walls 900 metres high. . . . Within a few months there arose in a clearing a large cabin, representing the station which was to be the first to span the world, with a dynamo borrowed from the Batavia Tramway Company driven by an aeroplane motor lent by the army [supplying a 100 kW arc]. . . . Holland was called up from November 1917 onward and experiments afterwards proved beyond doubt that even then *at the beginning of the telegraphic blockade* one-sided communication might have been established if something had been done on the other side *to make communication possible.* But practically



The Station Buildings in course of erection.

speaking Holland did *nothing.* . . . The station had been constructed on definite lines, did its work excellently well, but called in vain a whole year long *because no one on the other side moved a finger to rescue us from our isolation* . . . and if, by the middle of 1919 it was possible to speak of a first temporary communication between Holland and its East Indian possessions, this is entirely owing to the fact that a proper receiver was built in Java and sent to Holland; else another year would have been wasted."

"Instead of pushing forward the construction of a Dutch transmitting and receiving station the home authorities sent out a second temporary transmitter. The said transmitter of Telefunken manufacture possessed indeed double the primary energy of the Governmental transmitter, but was, owing to its injudicious equipment (only one mast 120 metres high and one single *long* wave) decidedly inferior to the one already in action, especially

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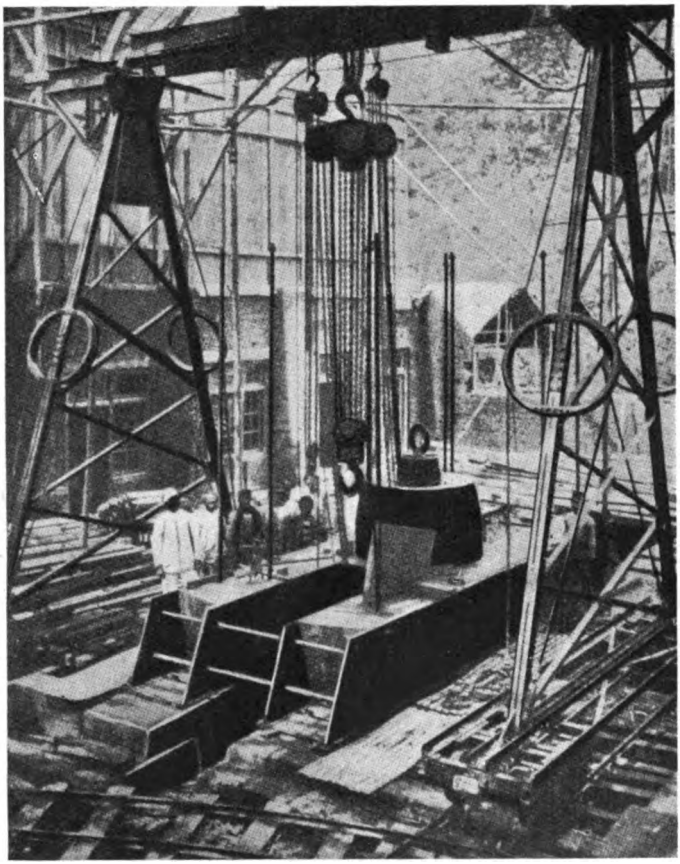
at nights, the only part of the twenty-four hours when communication with slight means was possible. The transmitter was of the so-called high-frequency generator type which only acts correctly in the case of an extremely constant line frequency and voltage, which, however, was unsuitable for this kind of work on account of the hand-regulated water-wheels which are used as prime-movers."



The Foundations for the Magnetic Circuit of the Arc.

" The first Bandung station owing to its larger permanent aerial was heard from five to ten times louder than the Telefunken station even when using *long waves*."

" Of course, the station also has points in its favour. Thus it is thoroughly reliable. Its drawback, however, is typical of all Telefunken stations supplied in this country, viz. far too little energy compared to the distance to be spanned."

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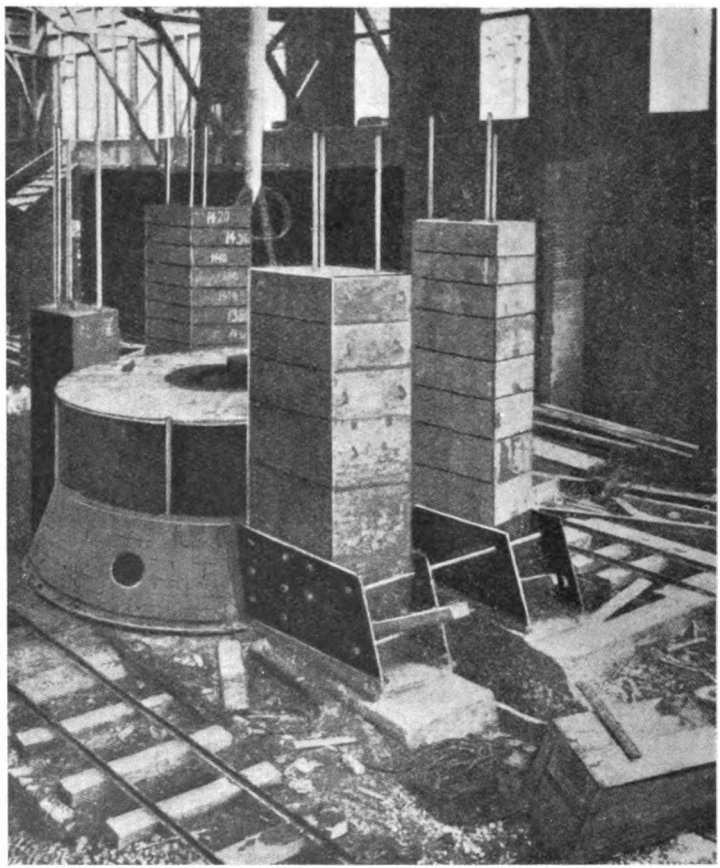
"Unfortunately it must be added that *during the war* the Government station was of no more practical use for communication with Holland than its rival. This was not our fault. Communication was established as soon as a receiver had been sent out to Holland. Communication was naturally faulty, audibility varied as is also the case in the East when receiving the large European stations. For really satisfactory communication the



Field Coil and Magnetic Circuit of the Arc in course of erection.

transmitter is from ten to twenty times too weak. But results have proved that its range is greater than that of any existing station, greater therefore than Nauen and of the permanent Telefunken station now in course of construction in Holland. This means that communication with the East Indies will become worse than the results in the reverse direction with temporary means up to now."

"Although the projects for—and the work on behalf of—the permanent

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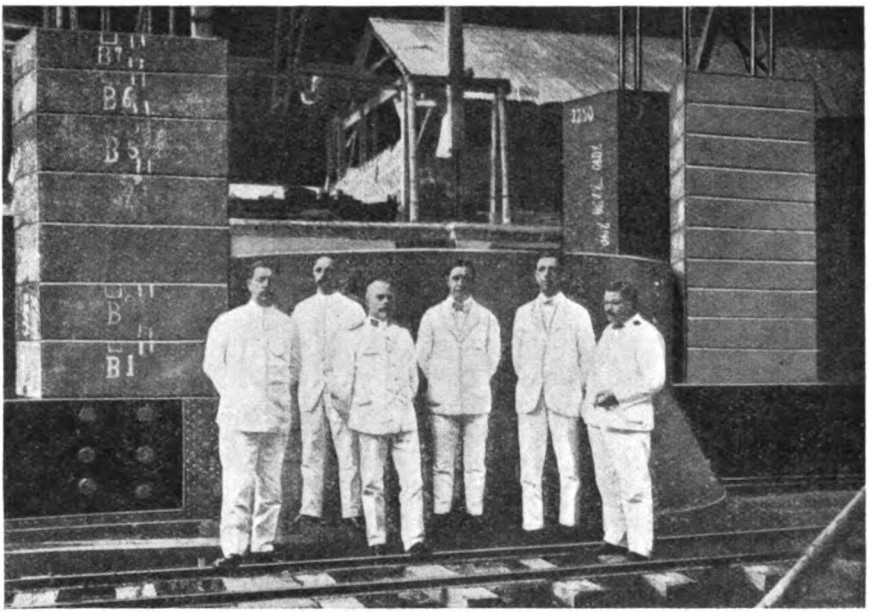
station were being pushed forward, it was tried at the same time to perfect the temporary station as much as possible. Thus the arc transmitter built for 100 kW output at long waves, was rebuilt in such a way as to be now capable of taking 165 to 320 kW according to the length of the wave employed. The combined aeroplane motor and tramway dynamo could only supply 65 kW. . . . As soon as a road had been made a twenty-year-old water turbine obtained from the Ketahoen Mining Company in liquidation was set up and was ready for action in August 1918. It originally drove the tramway dynamo and afterwards a more powerful dynamo giving 165 kW at 1,100 volts obtained from Japan, which still constitutes one of the principal



Side view of Arc Magnetic Circuit and Tank for Field Coil.

sources of energy for communication with Holland and Honolulu. As a second source of power connection with the Bandung city mains was obtained in July 1919 by means of a 25,000 volt three-phase overhead transmission line 35 km long and used to drive the 100 kW General Electric Company motor generator which arrived in December 1918. By combining these sources it became possible to supply the arc for long waves in the daytime up to 240 kW. A 200 kW motor generator purchased in Japan has now been set up in the new permanent station and a second turbine installation has been put up lower down the river. This plant generates 2,200 volt three-phase current which is conducted to the new station where a motor generator also purchased in Japan converts it into a direct current of 165 kW

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output. The wooden hydraulic pressure pipes had to be imported from Australia.

"As to the aerial, considerable improvements were introduced by replacing the original one which gave great satisfaction in the case of short waves (with 6 km wave the Antipodes had been reached), but could not be charged with more than 150 kW, by a much larger permanent aerial which constituted the first part of the permanent station. This aerial was ready in July 1919 and allowed the arc to be supplied with from 240 to 320 kW for long waves and as a result Java immediately got into touch with the colonial-built receiving station at Blaricum in Holland."

"As the permanent aerial in Java is already in position and the colonial receiving station in Holland has systematically collected data for over a year, it has for some time been possible to calculate with fair accuracy the energy required, the result being that the colonial transmitting aerial, to be powerful enough for reasonably accurate *commercial* intercourse, requires 1,200 to 1,800 kW swinging in it, *i.e.* three to four and a half times that of the most powerful European stations such as Bordeaux, etc. The arc input has therefore to be taken as high as 2,400 to 3,600 kW and the aerial will then be charged to the utmost voltage for which effective insulation is possible."

"The *power* having been determined, the *choice of system* was the next important point. Every large European country has as a matter of fact in the immediate neighbourhood of the Dutch frontiers enormously strong transmitter stations, producing in the receiving telephones of Dutch stations sounds so strong that the weak signals from the East Indies can never hope to compete with them, however strong the transmitting station over here is made. The only way to baffle such a disturbing station is to choose another wavelength. The disturbing station will try to follow suit, to resume its disturbing activity and it becomes a trial of skill between the operators. For this reason all military stations have a system which makes it possible to change the wavelengths rapidly and frequently. The *only system* which can do this in the case of very powerful stations is the *Poulsen system* with which the temporary Government station in the colony has consequently been fitted. Stations of the high frequency generator type, especially those with frequency multipliers such as characterise the Telefunken system, are absolutely unsuited for this kind of work."

"That the impracticability of the high-frequency generator for this kind of wireless communication is not a purely theoretical personal opinion appears from the fact that Blaricum reported soon after communication had been established that disturbances were regular with the following waves: 5, 6, 8, 10, 11, 12, 13, 14 km so that only waves of 7, 9 and 15 km remained practicable. The colonial Poulsen station had no difficulty in immediately using these waves; the temporary Telefunken station fitted with one invariable wave, could not do so, was interrupted beyond the hope of ever re-establishing communication and had to give it up. These were *accidental* disturbances in times of peace, which shows what would happen in war time."

"The Colonial Telegraphic Department therefore decided on a Poulsen

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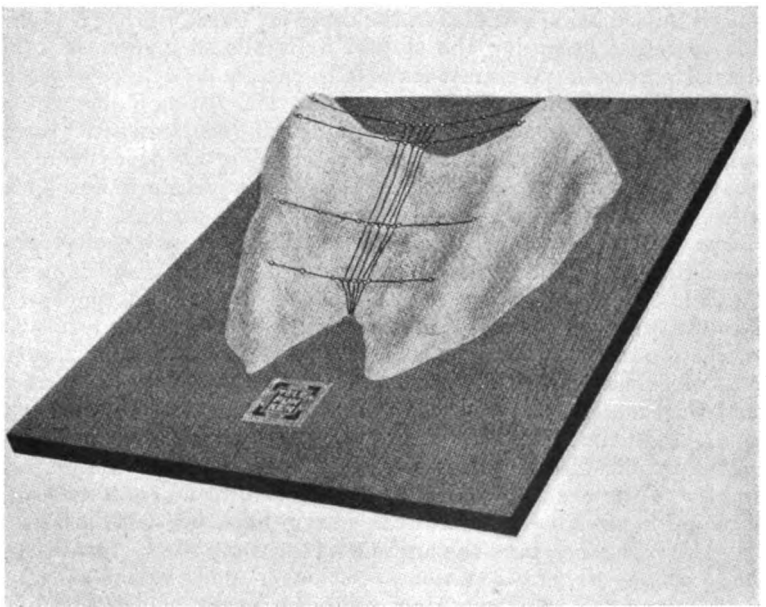
arc transmitter installation with an input of 2,400 to 3,600 kW. Basing himself on the necessary working data obtained from the temporary arc-lamp transmitter, Dr. de Groot undertook to design and have built in the colony a 2,400 to 3,600 kW arc-lamp transmitter, a transmitter two to three times as large as the world's largest (at Bordeaux) and construction was started in 1918. The manufacture of the giant arc involved the casting and working of 260 tons of cast and sheet iron in the Dutch Indies, delivery being adversely influenced by the fact that the parts must not be heavier than 6 tons with a view to the uphill transport, whilst by far the greater number of castings which were manufactured in the State railway shops at Bandung



A Scale Model of the Aerial System which is to be slung between the mountains on each side of the valley.

and Madioen which have a limited casting capacity only weighed from 1 to 2 tons, which necessitated a good deal of planing and involved extremely difficult constructions to build up the very heavy arc out of so many small parts. The winding of the magnet alone required 20 tons of copper; the bronze arc chamber which is being manufactured at the naval dockyard at Surabaya weighs nearly 6 tons. The *magnet system* two cores of which weigh 25 tons each and are moved by hydraulic power is rapidly approaching completion and only the *arc chamber* is still in course of construction so that the transmitter will before long be quite ready."

"The two motor generators of 800 to 1,200 kW on the D.C. side have now arrived from America. There are, however, foundations for two more such

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motor generators in order to increase the power to 3,600 kW with one set in reserve. There are also spare foundations for a second 2,400 to 3,600 kW arc transmitter in case one is needed.

" A special hydrogen generator supplies the necessary gas for the Poulsen arcs in order to keep these clean and in perfect working order."

" The walls of the station are of brick to a height of 4 metres and thence of teak wood with a view to earthquakes and high-frequency losses."

" We might end our description here were it not that a second station, standing cheek by jowl to the colonial one, is in course of construction. It is a Telefunken transmitter of the size of the one at Nauen, sent out to us by the Colonial Office in Holland quite independent of the colonial project. This Telefunken transmitter which is a copy of the one now being built in Holland, is indeed being installed at the company's risk, so that it is officially possible to refuse accepting the station if it fails to give satisfaction for commercial purposes. We must leave it to the reader's fancy to decide, in how far it will be possible to refuse an installation costing millions of money because it does not come up to the stipulated requirements. It will be impossible to blame the station for being useless for our purpose on account of the system itself. Its lack of suppleness in wavelength was known or might have been known if proper inquiries had been made."

" Hence the station has been designed as one whole with the Government station at the special request of the Telefunken Company and is to use the same aerial. It will prove an excellent reserve station in times of peace owing to the reliability which characterises the system. But during a great part of the year it will prove too weak for commercial communication with Holland. At times, however, when this work will have to be left to the more powerful Government station, it can be used for smaller distances (Japan, China, etc.). In times of war it will be doomed to silence."

" On the Dutch side the chances for regular communication are much less favourable. They are now building on the Veluwe moors a transmitting station equal in size to the Telefunken station here, but with a far inferior aerial. Although, therefore, the arguments for using the system in Holland are not so serious as here, a station not stronger than the one at Nauen, of which we have known the receiving results for years, will prove much too weak to be a worthy partner of the Government station at Malabar in commercial intercourse."

Carborundum and its Rectification Effect.*

By H. M. DOWSETT, M.I.E.E., F.Inst.P.

In the present paper it is intended to examine the chemical and physical nature of carborundum ; to describe those conditions which must be satisfied in order to produce the most reliable and best form of carborundum detector ;

* Received July 29th, 1921.

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to give the results of a number of experiments designed to elucidate the nature of the rectification effect; to suggest a theory for this effect in carborundum and to give the results of its application to the voltage-current characteristic; and finally, to describe a model of the carborundum molecule which would have the properties required to bring about the reactions described.

(1) Carborundum is a resistance furnace product of a crystalline nature made from the raw materials sand, coke, sawdust, and salt packed round a core of granular carbon and heated to a temperature of from 3,500° F. to 4,000° F.

It is supplied in irregular blocks about 3 inches to 4 inches square and from 1½ inches to 4 inches thick which although composed mainly of silicon carbide, SiC,—to the extent of 85 per cent. to about 97 per cent.—vary considerably in the chemical composition of the remainder, in crystal structure, electrical behaviour, density, hardness and colour. Each block in itself is, however, fairly consistent in its qualities, which suggests that these qualities depend to a large extent on the position in the furnace where the block was formed, and the temperature to which it was subjected. In what follows the base of the block refers to the less crystalline part which has been attached to the wall or floor of the furnace.

(2) In order to grade the crystal according to its capacity to rectify weak currents a small piece is chipped from each block, a good electrical contact over a wide area is made at one part of it which is then known as the base of the crystal, and a good electrical contact is also made at an edge or point on the crystal which is found by trial to rectify the current, and is referred to as the point of the crystal.

The current-voltage characteristic of the sample is then taken in the usual way.

The varieties are found to classify into five distinct groups :—

(*a*) A close packed light green crystal which is free from dust. It is full of irregular but parallel fissures normal to the base of the block. The lowest potential difference at which a rectified current will flow through it is obtained when the base of the crystal is connected to the positive pole of the battery. It is therefore known as positive crystal.

It has very few neutral conducting points and no negative. Compared with other grades of carborundum its resistance when suitably mounted is low.

(*b*) A close packed steel-grey crystal inclined to be dusty and graphitic. This also has fissures. Some of its sensitive points react like positive crystal, some like negative, but all have high resistance characteristics This variety has the least number of neutral conducting points.

The steel-grey crystal sometimes merges into the light green.

(*c*) A looser packed dark grey crystal and a black crystal, with the usual fissures. These varieties are predominantly negative but very occasionally a high resistance positive point can be found. There are always many neutral conducting points.

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(*d*) A brittle multicoloured crystal with a colour basis of dark green, dark grey, or black, and having fissures. Electrically there are two distinct varieties which have this same appearance. One of them is decidedly positive, has a low resistance and many neutral conducting points, the other is negative, but is a poor rectifier, has a high resistance and very few neutral conducting points.

(*e*) A close packed grey or black crystal, sometimes multicoloured on the surface of the block and with no fissures. It conducts but it does not rectify.

(3) A spectroscopic and chemical analysis shows that the principal impurity is iron which varies from 3 per cent. to 8 per cent., the best positive and negative crystal in a recent analysis having least iron.

There is a little aluminium present in all varieties.

There are heavy traces of magnesium and calcium in the green, sodium is present in the multicoloured and black non-rectifying crystal, but the black negative except for the iron appears to contain the least amount of other elements than carbon and silicon. It contains however a certain amount of free carbon and free silica which are not present in the positive green.

(4) Carborundum has been classified by Baumhauer in the tourmalin group.

Under a high power microscope the crystals in all blocks having fissures are seen to be massed irregularly but with a strong tendency to layer parallel to the base of the block and at right angles thereto, that is along the length of the fissures. The crystals parallel to the base are small but fairly regular in shape, those parallel to the fissures are long and irregular.

The green positive crystal has the appearance of hexagonal and rhombohedral slabs, the black negative of hexagonal flakes, the relative thicknesses under a magnification of 36 diameters being comparable to green window glass and a sheet of paper.

The greater thickness of the green positive crystal accounts for its greater mechanical robustness.

The colouration of the multicoloured blocks is seen to be due to interference effects in the top crystal layers which appear to be partially destroyed or fused as the crystal has lost all definition.

It is said to be caused by the oxidisation of the impurities in carborundum when a furnace is opened before being allowed to cool.

The black conducting and non-rectifying blocks having no fissures show masses of irregular crystals more nearly related to the negative variety than the positive, but having no definite arrangement, with veins of spongy coke-like material in which occasional single crystals are embedded.

Fissures are produced by the escape towards the centre of the furnace of the gases of combustion, their absence indicates that the blocks were in a position whence the gases and light vapours could not escape, and the presence of the coke, of sodium as mentioned in section **(3)**, and the neutral conducting quality of the material are thereby explained.

Apart from acting as channels for purifying the material the fissures as already pointed out give a structural grain to the block, and this is accom-

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panied by an electrical grain as rectification takes place normal to the base and neutral conduction at right angles thereto. The fissures also provide the space necessary for the growth of perfect crystal edges and faces without which the rectification effect cannot be demonstrated.

The microscope shows that the neutral conducting points in green positive crystal are badly fractured crystal edges, but in black negative crystal they are more often faults where the growth of the crystal has been interrupted by the presence of some impurity.

(5) The influence which the nature of the contact of wide area has on the characteristic of the crystal is shown by the series of curves Fig. 1.

A green positive carborundum crystal was first mounted in solder, search was made for its most sensitive point contact, and the characteristic was taken with a steel plate on this contact.

The solder was then melted off the end of the crystal which was next plunged into molten brass and allowed to set.

This brass-tipped crystal was afterwards mounted in solder in the standard brass cup, its most sensitive point was found and a second characteristic was taken. These operations were repeated with steel. Platinum was also tried but in this case no suitable junction could be obtained.

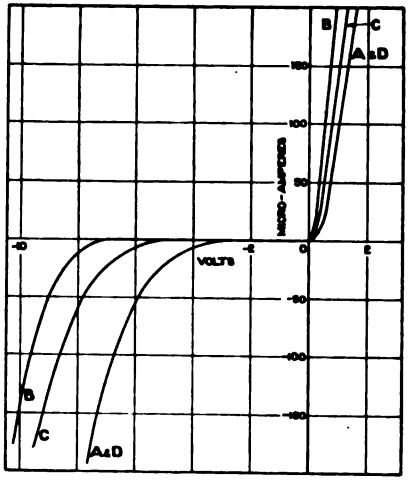

FIG. 1.—Characteristic Curves showing Influence of Nature of the Contact.

Curve A = Mounted in solder.
Curve B = Steel tipped.
Curve C = Brass tipped.
Curve D = Again mounted in solder.

TELEPHONE SHUNTS.

A and D = 120 ohms.
B = 20 ohms.
C = 20 ohms.

Fig. 2 gives the characteristics of a positive crystal B tipped successively with brass, copper and steel, and of a negative crystal A tipped successively with steel and tungsten.

The author found that if suitable care were taken of the point of the crystal it was possible to use these metals one after the other on the same crystal and then on returning to solder to obtain a repetition of the first characteristic without any difficulty.

The face of the carborundum on which the contact of wide area was made was undoubtedly altered by these changes without altering the characteristic. The quality of the contact therefore appeared to be of much greater importance than the loss or fracture of a small amount of crystal. The internal resistance of the crystal excluding the rectifying point and in comparison with the resistance of the contact of wide area must therefore be assumed to be very low. There are other facts which have a bearing on this question which will be stated later.

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The characteristics obtained show that the best results are given by steel and tungsten, the metals which melt at the highest temperatures and nearest to the temperature at which carborundum is formed or changes its state. Also it is probable that steel when molten has a stronger affinity for carborundum than other metals owing to the iron and carbon contained in the crystal itself. And again as steel and tungsten are among the hardest metals,

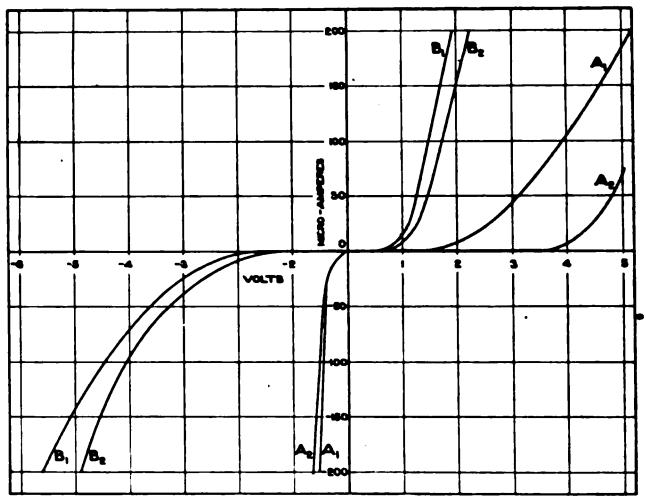

FIG. 2.—Characteristic Curves showing Influence of Nature of the Contact with Positive and Negative Crystal.

Curve A_1 = Steel tipped negative crystal.
Curve A_2 = Tungsten tipped negative crystal.
Curve B_1 = Steel tipped positive crystal.
Curve B_2 = Brass and copper tipped positive crystals.

on cooling from these higher temperatures the pressure exercised by contraction must be much greater in their case than with copper, brass or solder.

This pressure can operate in two ways, first by improving the actual electrical contact, and second by mechanically fracturing the outer crystal layers, which, as shown in section (4), will produce or extend the neutral conducting area.

The improvement which results from steel tipping is in general less marked but still appreciable when applied to black negative crystal. In this variety the neutral conducting points are more numerous and are mainly caused by impurities, and it is possible that solder makes a better electrical contact to these impurities than to carborundum itself.

(6) From a commercial point of view the principal improvement which resulted from the steel-tipping process was that about 85 per cent. to 90 per cent. of the raw crystal supplied by the Niagara Falls Company could be employed for rectifying purposes instead of the usual 20 per cent. or 25 per cent. if the crystals were simply mounted in plain solder.

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The increase was almost entirely made up of the hard green positive variety which has a much greater contact resistance to solder than has the dark grey or black negative variety, so much so that crystals of this type which prove to be of comparatively low resistance when steel tipped, commencing to rectify with a steep characteristic when only a fraction of a volt is applied, when mounted in plain solder may show no current in either direction when two volts positive or negative is applied, or may give a high resistance characteristic unsuitable for use in practice.

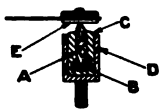

FIG. 3.—Arrangement of Crystal and Contact.

The crystal detectors under the observation of the author are made entirely from green positive or black negative carborundum the two most suitable varieties, and are constructed as shown in Fig. 3 where A is a crystal chip tipped with steel at B, and set in solder C, in a brass cup D, which is painted red if the crystal is positive and black if the crystal is negative.

The steel plate mounted on a strip spring which makes contact with the rectifying point of the crystal is shown at E and is usually set to exert a pressure of 400 to 500 grammes, or roughly 1 lb.

The official test for such a detector is that it shall pass a current of at least

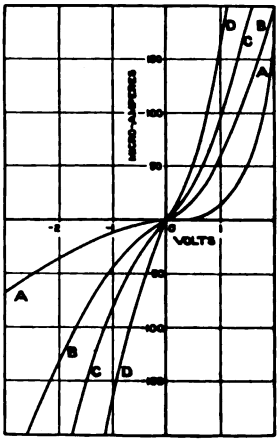

FIG. 4A.—Crystal mounted in Solder only.

TELEPHONE SHUNTS.

A = 20 ohms.
B = 40 ohms.
C = > 200 ohms.
D = No signals.

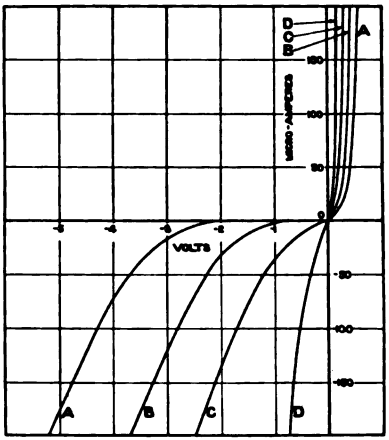

FIG. 4B.—Crystal Steel Tipped and mounted in Solder.

TELEPHONE SHUNTS.

A = 20 ohms.
B = 40 ohms.
C = 120 ohms.
D = > 200 ohms.

CHARACTERISTIC CURVES SHOWING EFFECT OF CONTACT AREA.

Curves A = Steel contact.
Curves B = Mercury just touching.
Curves C = Contact immersed 1 mm. in mercury.
Curves D = Contact immersed 3 mm.

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250 microamps when 2 volts are applied to it in one direction but no current whatever when the same voltage is applied in the opposite direction, and it is also compared for sensitivity on signals against a standard.

(7) The metal used for the strip spring making contact to the point of the crystal does not appear to be a matter of great importance provided the strip presents a plain undented surface.

The best results are obtained when the area of contact is as small as possible, but with an abrasive material like carborundum the crystal point will scratch and enter deeper into brass than into steel so that for this reason the harder metal is to be preferred.

The effect of extending the area of contact is illustrated in the series of characteristics of Fig. 4. A steel plate contact as shown by curves AA has a higher resistance than a mercury contact which is just touching the crystal point, but the sensitivity with the steel is greater than with the mercury.

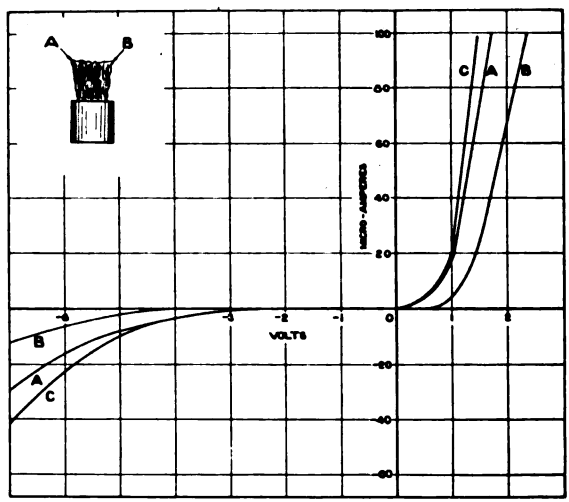

FIG. 5.—Curves showing Effect of using Contacts in Parallel.

Curve.	Point of Contact.	Sensitivity: Telephone Shunt.
A	A	100 ohms.
B	B	120 ohms.
C	A and B in parallel.	100 ohms.

As the area of contact of the mercury is increased the detector resistance falls but so does its sensitivity.

The effect of increasing the number of point contacts is also illustrated in Fig. 5.

Contact B offers a higher resistance and is less sensitive than contact A.

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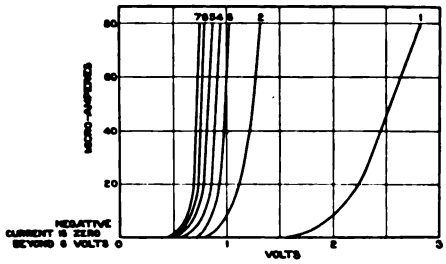
If the two are connected in parallel the total resistance is less than either and the sensitivity is that of the lowest.

This is a case of selected points but with a broad mercury contact, no such selection could be exercised.



Curve.	Pressure. Grammes.	Sensitivity: Telephone Shunt. Ohms.
1	Light contact.	100
2	100	85
3	200	80
4	400	80
5	600	80
6	800	80
7	1,000	80

Average pressure = 453 grammes = 1 lb.

FIG. 6A.—Effect of Contact Pressure on High-resistance Positive Crystal.

(8) The effect of contact pressure at the crystal point is shown in the series of curves Figs. 6A, 6B, 6C, and 6D.

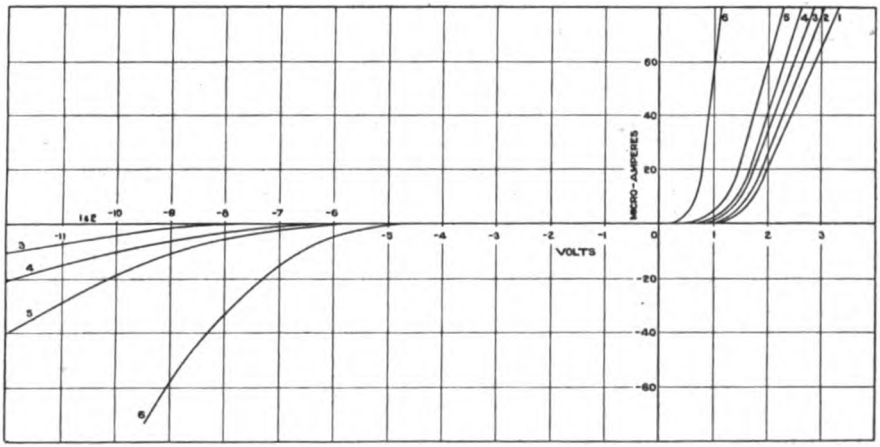


FIG. 6B.—Effect of Contact Pressure on Low-resistance Positive Crystal.

Curve.	Pressure. Grammes.	Sensitivity: Telephone Shunt. Ohms.
1	Light contact.	100
2	100	100
3	200	95
4	300	95
5	400	95
6	2,500	80

Average pressure = 453 grammes = 1 lb.

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In Fig. 6A the pressure applied to a high-resistance positive crystal was increased from a light contact up to 1,000 grammes. This caused a corresponding fall in the effective resistance and the potential at which the current appeared, but the sensitivity of the crystal as a detector only increased slightly up to 200 grammes pressure and then remained constant up to a pressure of 1,000 grammes.

Fig. 6B refers to a positive crystal of lower resistance. Similar effects were noticed but it was possible to take the pressure up to 2,500 grammes with a 20 per cent. improvement in sensitivity.

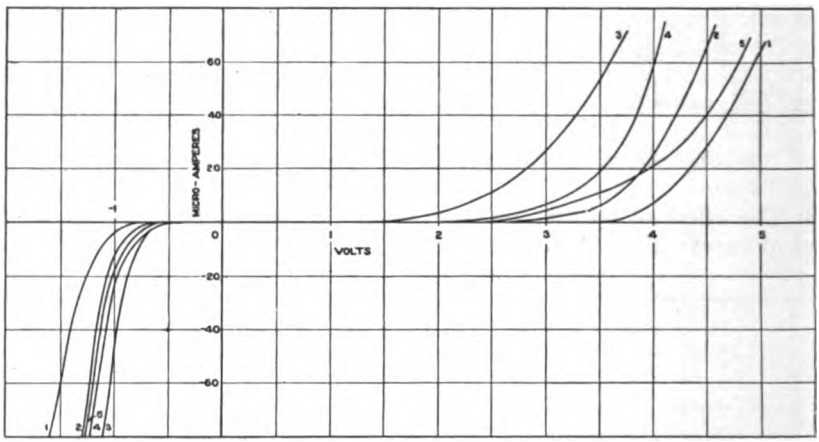

FIG. 6c.—Effect of Contact Pressure on High-resistance Negative Crystal.

Curve.	Pressure. Grammes.	Sensitivity: Telephone Shunt. Ohms.
1	Light contact.	100
2	100	95
3	200	95
4	300	95
5	400	95

Average pressure = 453 grammes = 1 lb.

In Fig. 6c a negative crystal of fairly high resistance showed a small improvement in conductivity up to 200 grammes and then fell off again as the pressure was increased up to 400 grammes. Its sensitivity remained constant above 100 grammes.

Finally in Fig. 6D a negative crystal of a lower resistance improved steadily in conductivity but not in sensitivity as a detector.

These results show that the contact pressure is not critical. It need only be sufficient therefore to make the adjustment insensitive to local vibration.

At the working pressure of 400 to 500 grammes the results just quoted show that the sensitivity has practically reached a constant value.

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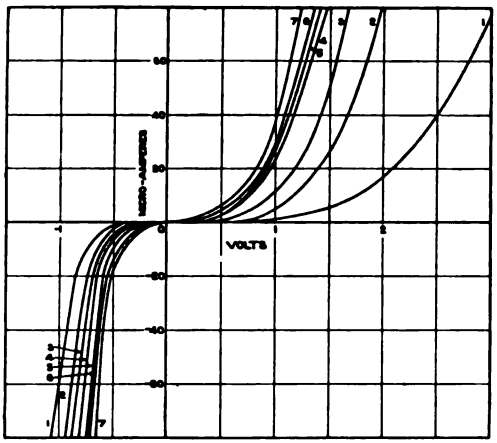
(9) The effect of pressure applied to a neutral point on the resistance of a crystal measured from the neutral point to the steel-tipped base is shown in Figs. 7A and 7B.



Curve.	Pressure. Grammes.	Sensitivity: Telephone Shunt. Ohms.
1	Light contact.	100
2	100	100
3	250	100
4	500	100
5	750	100
6	1,000	100
7	2,500	100

Average pressure = 453 grammes = 1 lb.

FIG. 6D.—Effect of Contact Pressure on Negative Crystal of Lower Resistance.

The plots in Fig. 7A were obtained when using a green positive crystal, the neutral point being provided by a jagged crystal edge. In this case a change of pressure from 100 grammes to 2,500 grammes lowered the resistance from 5,000 ohms to 500 ohms.

The plots in Fig. 7B were obtained when using a black negative crystal the neutral point being provided by foreign matter in a fault in the crystal. In this case the resistance was 6,250 ohms for a pressure of 100 grammes, it started to fall and then rose as the pressure was increased and finally fell again, being 550 ohms when the pressure reached 2,500 grammes.

It was found that this irregular decrease and increase with pressure was a permanent feature of this point on the crystal.

One is likely to conclude from these results that the improvement noted from steel tipping can be explained by the great contact pressure exercised by the shrinking of the steel when cooling, but it will be made clear later that this cannot be the complete explanation.

(10) Having thus determined the conditions of contact at the base and point of a crystal chip which must be satisfied in order to obtain consistent results, it is of interest to show how the characteristic of a crystal block alters in proceeding from the part which has been attached to the furnace wall,—the base,—to the part which has been nearest the furnace core,—the top of the block.

For this purpose some of the thickest blocks obtainable were selected, sample chips were taken from different levels, they were mounted in the standard manner and were then tested in the usual way.

Figs. 8A and 8B for green positive carborundum show that the rectification

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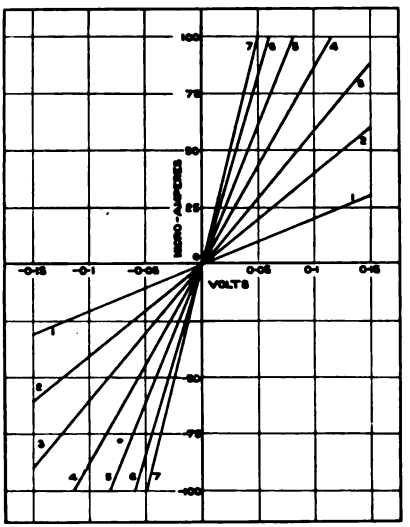

FIG. 7A.—Green Positive Crystal.

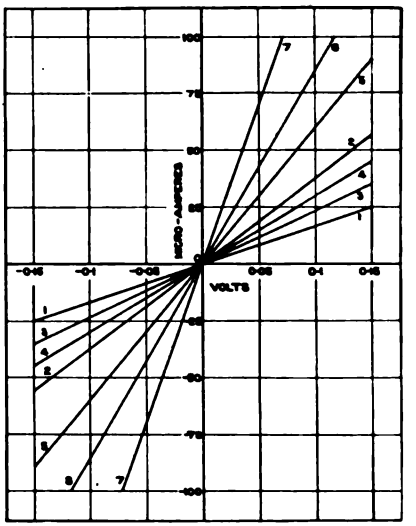

FIG. 7B.—Black Negative Crystal.

EFFECT OF PRESSURE APPLIED TO A NEUTRAL POINT ON THE CRYSTAL.

Curve.	Pressure.		
	Grammes.	Lbs.	Ozs.
1	100	—	3·53
2	250	—	8·82
3	500	1	1·64
4	1,000	2	3·28
5	1,500	3	4·92
6	2,000	4	6·56
7	2,500	5	8·20

effect and the resistance are greatest at the base of the block and least at the top, and Figs. 9A and 9B for negative crystal show the same effect.

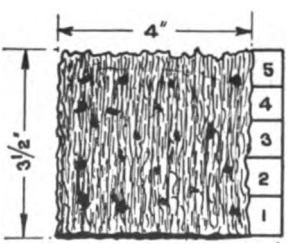

FIG. 8A.—Section of Block of Positive Carborundum.

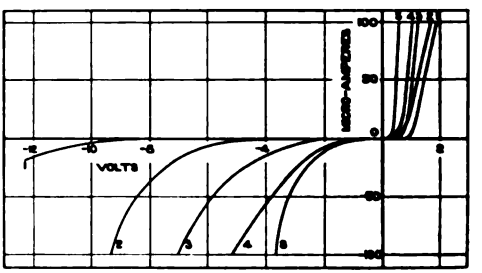

FIG. 8B.—Variation of Rectification Effect with Position in Block (Positive Crystals).

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The best detector crystal in each case, however, is usually obtained from the position of the second layer.

The sense of the rectification is the same throughout the whole block, and, as shown in Fig. 9B, does not depend on which end is made the point and which the base. The degree of rectification does depend on this in the lower layers but not in the top.

The base of the negative block has an amorphous coke-like nature, and if the top of the first layer is steel tipped usually only neutral conducting points can be found on the bottom. The top of the first layer is composed of small crystals and the top of the sixth layer of large crystals.

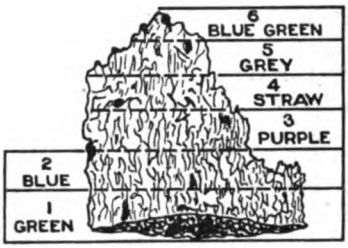

FIG. 9A.—Section of Block of Negative Carborundum.

Practically all the crystals in the block are faulty; they grow one out of

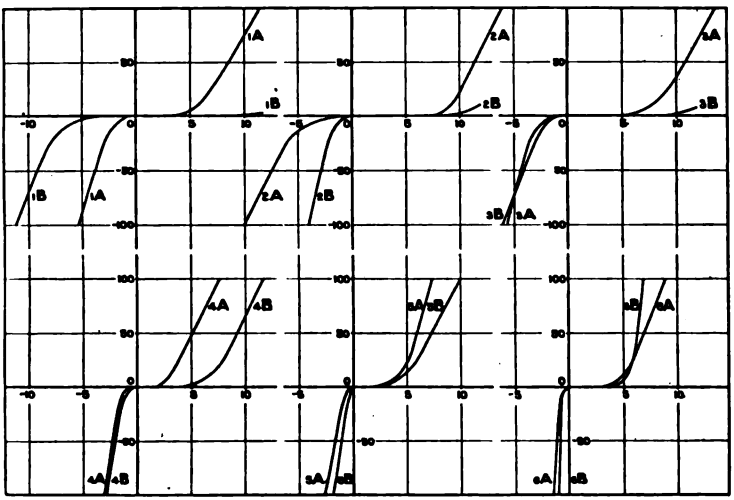

FIG. 9B.—Variation of Rectification Effect with Position in Block (Negative Crystals).

Curves A = Crystal base nearest to top of block.
Curves B = Crystal base nearest to base of block.

NOTE: The numbering of these curves corresponds with the sections numbered in Fig. 9A.

the other or one group out of another group, and where they are thus grafted together they conduct. With the possible exception of some parts of the first layer active rectification can only take place at the surface point contact, as any interior point contacts are short circuited by the surrounding grafted crystals.

The degree of rectification and the effective resistance of the crystal chip would appear therefore to be dependent inversely on the size of the surface crystal to which the point contact is made.

The effect of chemically cleansing the crystal surface of oxides, either by heating in fused borax, or by boiling the samples in a mixture of nitric and

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hydrofluoric acid, and then in a mixture of nitric acid and potassium chlorate, is to produce an extraordinary consistency in the characteristics of all samples from the same layer, but the difference between the characteristics of one layer and another is not affected.

(11) What influence has the air at the point contact on the rectification effect ?

A standard carborundum and steel plate detector after being adjusted was mounted in a glass chamber which could be exhausted of air. Its characteristic was taken and its maximum sensitivity was measured by the shunted telephone method at different air pressures.

It was found that for air pressures from normal down to 0·00001 mm of mercury at constant temperature there was no change in the characteristic or in the sensitivity of the crystal.

The conclusion is that with carborundum and with the normal spring contact pressure on the crystal point, the air at the point plays a negligible part in the rectification effect, which must therefore be due to a reaction in the thickness of the crystal itself.

(12) The influence of temperature is considerable.

The chamber containing the detector was heated in steps from 19° C. to 100° C.

The characteristic became progressively steeper and the sensitivity of the detector increased until at 100° C. the telephone shunt resistance was half that required at 19° C. to give the same audibility.

This indicates that a carborundum crystal detector employed in the tropics will give better results than when it is used in temperate latitudes.

At 100° C. a variation of air pressure from 760 mm to 0·00001 mm made no difference to the behaviour of the detector.

A test was made to find out whether the change in the characteristic with temperature was due to a thermo-electric effect at the contact. For this purpose a D'Arsonval type of galvanometer capable of detecting an E.M.F. of 0·00025 volt was employed. The detector enclosed in the glass containing vessel was heated up to 140° C. but no deflection was obtained.

(To be concluded.)

Graphical Symbols for Radio Diagrams.

The interpretation of circuit diagrams used in explanation of radio apparatus is considerably simplified if standardised symbols are always used in their preparation. For some time past we have adhered as far as possible in the RADIO REVIEW to a uniform scheme of such symbols, but in view of the increased interest that has recently been taken in this subject we are setting out in the following pages a list of the most important symbols that are at present being used, or that are proposed for use in the RADIO REVIEW. These have been compiled so as to be in agreement as far as practicable with the symbols that are most commonly employed in British, American, French, German, and Italian radio literature, keeping in mind the necessity for both clearness and ease of drawing. An alternative is shown for the three-electrode thermionic valve.

Comments as to the merits or demerits of these suggested symbols will be welcomed from readers, with any suggestions as to additions or other changes which might make this list more complete and useful.

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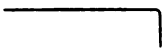
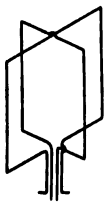
Aerial—Elevated.


Aerial—Horizontal or Buried.


Aerial—Directional.

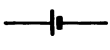
Terminal.

Connection — Electrical Joint.

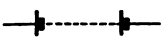
Bridge—Crossing.

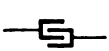
Earth.

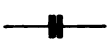
Counterpoise.

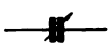

Cell. (The long thin stroke represents the Positive Terminal.)

Battery—L.T.


Battery—H.T.


Condenser—Large, Audio Frequency.


Condenser—Fixed Radio Frequency.

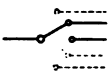

Condenser — Variable (continuously) Radio Frequency.

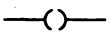
Telephones.

Microphone — Telephone Transmitter.

Fuse.

Switch—Single-way.

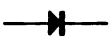

Switch—Multi-way.


Switch—Plug.

Plug.

Key—Morse Tapping.

Key—Morse, Back Contact.


Detector—Crystal.

Coherer.

Tikker.

Detector—Magnetic.

Rectifier. (Electron Current Flow assumed from Point to Plate.)

Valve—Tube Thermionic. (Alternative — 1.)

Lamp—Bulb Electric, Filament.

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Spark Gap—Open.

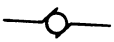
Spark Gap—Quenched.

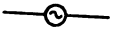
Spark Gap—Rotary, Synchronous.

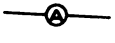
Spark Gap — Rotary, Asynchronous.

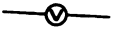
Arc—Open.

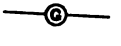
Arc—Enclosed.

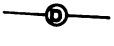

Generator—D.C.


Generator—Alternating.

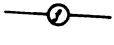

Ammeter.

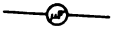

Voltmeter.

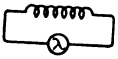

Galvanometer.


Decremeter.

Wattmeter.


Frequencymeter.


Microfaradmeter.

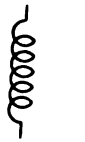

Wavemeter.

Thermoammeter.

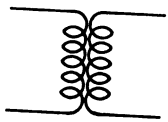
Resistance—Fixed.

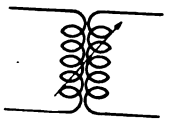
Resistance—Variable.

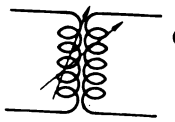
Potentiometer Resistance.


Inductance.

Inductance—Variable.


Coupling—Inductive.


Coupling—Inductive, Variable.


Coupling — Inductive, Variable, one Inductance variable.

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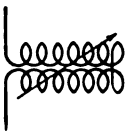
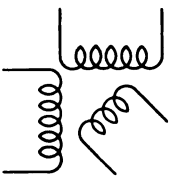
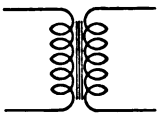
Choke Coil—Iron Core.



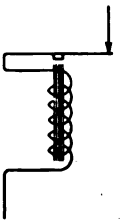
Variometer.



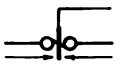
Radiogoniometer.



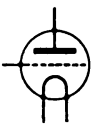
Transformer—Iron Core.



Vibrator—Buzzer Make and Break.



Relay.



(Alternative — 2.) Valve —Tube Thermionic.

Notes.

WIRELESS TELEPHONY ON THE "QUEST."—Sir Ernest Shackleton's expedition on the *Quest* has been fitted out with wireless telephone apparatus in addition to its regular wireless equipment. Two 100 watt "Y.B." type Marconi C.W. and telephone sets have been fitted, one being for base work on land. The Avro aeroplane which is being taken has also been fitted with a similar set. [4305]

ANNUAL CONVENTION.—The first Annual American Radio Relay League Convention was held in Chicago between August 30th and September 3rd. Many important papers on the subject of radio work were read and discussed. [4163]

DAMAGE TO ARLINGTON RADIO STATION.—In a recent severe electrical storm the U.S. Naval Radio Station at Arlington was struck by lightning and had temporarily to suspend operations. The interruption however was of short duration. [4003]

A new Weights and Measures Law has been passed in Japan rendering compulsory the use of the metric system. The complete change-over from the existing system is to be effected in all works, schools, Government offices, etc., in a period not exceeding five years. [3147]

It has been stated in the House of Commons in reply to inquiries that no alteration is contemplated in the existing rules with respect to wireless "watchers" on ships. [3029]

THE SHIPPING, ENGINEERING AND MACHINERY EXHIBITION which was held at Olympia, London, W., between September 7th and 28th, included several items of radiotelegraphic interest exhibited by various manufacturers. Particular mention may be made of the apparatus exhibited by the Radio Communication Co., Ltd. (marine spark and arc installations); the R.M. Radio Co., Ltd. (see RADIO REVIEW, 2, pp. 172—179 for illustrated description); H. Hamilton Wilson (motor driven interrupter type of transmitters, high-tension condensers, and a complete ½ kW set); the British Thomson-Houston Co. (portable wireless receiving apparatus); F. O. Read & Co. (amateur wireless apparatus and components); S. G. Brown (telephones). [4241]

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Two New Negative Resistance Devices for Use in Wireless Telegraphy.*

By JOHN SCOTT-TAGGART,

Chief of the Patent Department, and Research Engineer, Radio Communication Co., Ltd.

The paper opens with a short account of the uses of negative resistances, the chief being the production of continuous oscillations for use in wireless telegraphy. The author then describes two new thermionic valve devices by means of which negative resistance characteristics may be obtained. The first device, termed the "Negatron," was produced in September, 1919 (*British Patent* 166260). The principle on which it works is briefly as follows: A thermionic valve is arranged having two flat anodes one on each side of a filament. Each anode is connected through an anode battery to the filament so that the electrons emitted by the filament, when it is heated to incandescence, are distributed fairly equally between the two anodes. A control electrode, which may be a flat grid, is also arranged within the valve between the filament and one of the anodes. This latter anode will be called the "diversion anode," while the first one will be called the "main anode." If we suitably arrange the relationship between the electron emission and the anode voltages, we may make the total of the anode currents approximately equal to the electron emission. In other words, a saturation effect is obtained. Under these conditions, if we make the grid more positive with respect to the filament we shall divert electrons from the main anode to the diversion anode, with a consequent reduction of the current flowing in the main anode circuit. In the negatron, as preferably used, the main anode is connected to the grid so that when the main anode voltage is increased the grid potential is increased, electrons are diverted from the main anode, and the main anode current decreases. Hence the negative resistance effect.

Theory of Action of the Negatron.—Fig. 1 illustrates the negatron valve itself. The anode on the left is the main anode (usually small), while the anode on the right is the diversion anode. Between the filament and the diversion anode is a flat openwork grid. A tubular valve with four-pin cap is preferred, the connection to the main anode being taken to the metal portion of the valve cap. A metal spring on the holder presses against and makes electrical contact with this metal portion.

FIG. 1.

The action of the negatron will be best understood if reference is made to Fig. 2, which shows a negatron connected up in one way so as to possess negative resistance characteristics. Between the anode A_1 and the filament F is a battery B_2 and two terminals I, N. Between these terminals a milli-ammeter may, for the time being, be connected. The anode is connected through a battery B_3 to the grid G. This battery is merely connected in this position to keep the grid at a suitable potential which is preferably slightly negative. If G were connected directly to A_1, G would have a high positive potential with respect to F. Between F and the diversion anode A_2 is a second battery B_2'. Both B_2 and B_2' are usually of about 60 volts, but their values are not very important provided that the current supplied to the filament F may be adjusted to produce the saturation effect.

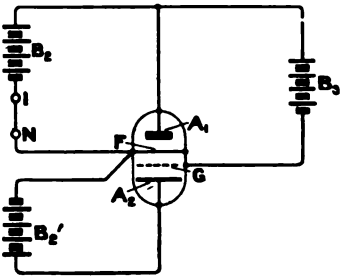

FIG. 2.

Let us now see what will happen if we increase the voltage of B_2. We should normally expect the current to A_1 to increase, but as the potential of A_1 increases so does that of the grid G. Since G becomes more positive, the current

* Abstract of papers read before Section G of the British Association at Edinburgh on Tuesday, September 13th, 1921.

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to A_2 will increase, and this increase could be measured by connecting a second milliammeter in the A_2 anode circuit. This method of varying (by altering the space charge) the current to A_2 is, of course, well known, as it has been used in ordinary valves since Lee de Forest first introduced the grid. The important fact to notice, however, is that, if the current to A_2 increases, the electrons which go to A_2 must come from those which would have gone to the anode A_1. There is, therefore, a diversion of electrons. If the A_2 anode current increases, the A_1 anode current must decrease, and conversely. Similarly, a decrease of the A_1 anode current would always be accompanied by an increase of the A_2 anode current, and conversely. This effect is conditional on the existence of saturation in the valve. Since by increasing the potential of the main anode A_1 we have diverted electron current to the anode A_2, the main anode current decreases. There are now two effects which govern the A_1 anode current. The increase in the A_1 anode potential tends to increase the A_1 anode current; the diversion effect, however, tends to decrease the A_1 anode current. The diversion effect greatly outweighs the other, and the result is a decrease in the main anode current consequent on an increase of the main anode potential; the converse also applies. A decrease of the main anode potential makes the grid G more negative and decreases the current to A_2; the A_1 anode current consequently increases. In this way, the negatron acts as a negative resistance.

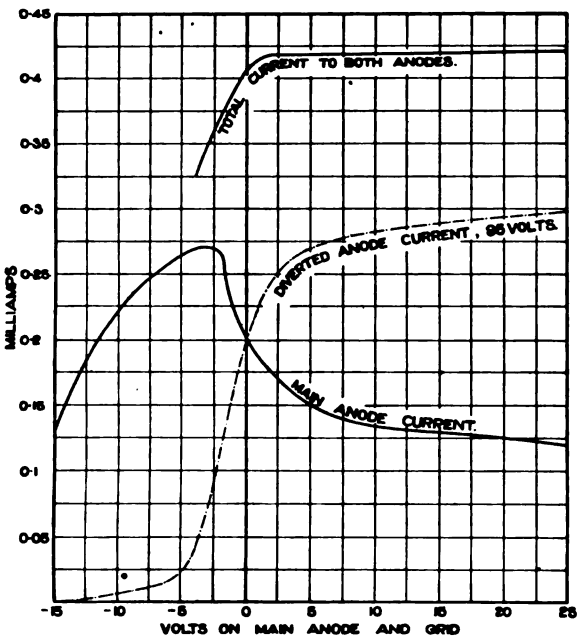

Fig. 3.
(Main anode datum = + 95 V.)

The negatron, as described, works only when the saturation effect is obtained. For this reason, a filament current rheostat is desirable and the current through the filament is adjusted until the negative resistance effect is obtained. If the filament be too bright, there will be no "robbing" action; there will always be a plentiful supply of electrons around the filament and an increase of grid potential would increase the A_2 anode current and the additional electrons would come from the source round the filament and not from amongst those which would have gone to the main anode A_1. The A_1 anode current would therefore be unaffected and no negative resistance effect would be obtained.

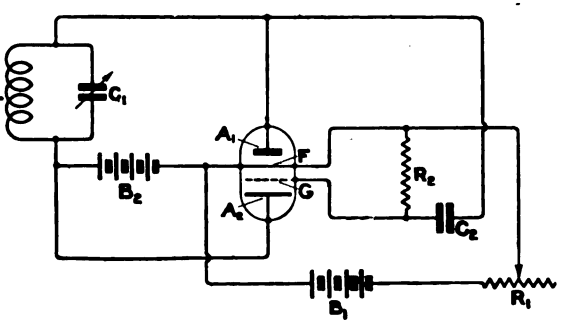

Fig. 4.

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Characteristic Curves of the Negatron.—The above explanation is borne out by characteristic curves obtained with the negatron, three of which curves are shown in Fig. 3. The thick line shows the main anode current. The top thin curve shows the sum of the two anode currents. The broken line represents the diversion anode current. Since the grid is always kept in the neighbourhood of zero volts, the grid current is almost zero. The grid is usually kept slightly negative, so that the grid current is zero. If this were not so, the grid current would add itself to the main anode current and the negative resistance slope would be less steep.

The curves of Fig. 3 bring out very clearly the "robbing" action which the negatron utilises. The top curve shows that the negative resistance effect is obtained while the valve is saturated. Since the total current remains constant and the diversion anode current increases (due to the control electrode potential rising) the main anode current must of necessity decrease, and this is shown by the thick line curve which slopes downwards. The main anode current decreases to the left of the peak because the saturation effect is non-existent (as proved by the top curve) and the decreasing grid potential produces an increasing space charge between filament and main anode which decreases the main anode circuit. The curve is, of course, only used along its downward sloping portion and oscillations will only be produced when the main anode and grid potentials are at suitable values. In practice, the grid potential is usually slightly negative and no grid voltage adjustment is necessary.

Applications of the Negatron.—To recount the applications of the negatron would take up too much space; they are as numerous and varied as those of the dynatron (which, of course, works on an essentially different principle). The main use of it is as a generator of continuous oscillations for the transmission or reception of continuous waves. It may be used for receiving spark signals by reducing the effect of positive resistance. As a local oscillator it is exceedingly convenient as it will oscillate on all ranges from 600 m to 20,000 m (the usual commercial range) without any complicated switching arrangements. The circuit arrangements which have been found most convenient are shown in Fig. 4. These are the same as those in Fig. 2, except that the two batteries are replaced by a single one B_2 of about 60 volts. The main anode is connected through a leaky grid condenser C_2 to the grid G, a resistance R_2 being connected across grid and filament. This leaky grid condenser merely replaces the battery B_2 of Fig. 2 for the purpose of avoiding a high positive grid potential. The filament F is heated by current from the 6-volt accumulator B_1 through the rheostat R_1, of about 7 ohms resistance. This rheostat is adjusted until continuous oscillations are produced in the oscillatory circuit L C_1. It is to be noted that the diversion anode circuit plays no other part in the circuit than as a path round which electrons are shunted. The A_2 anode current produces no effect whatever on the oscillatory circuit L C_1. If this anode were disconnected, the circuit would not, of course, oscillate even if there were plenty of electrons because the phases of the grid potentials would be exactly opposite to those necessary to produce oscillations. As it is, the grid, over (and beyond) the working range, does not control the main anode current in any way, when the A_2 anode is disconnected.

FIG. 5.

Fig. 5 is a photograph of a commercial negatron oscillator designed for use as a local oscillator for beat reception. The circuit arrangements are similar to those of Fig. 4. A metal plate is preferably connected to a point along

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the inductance. This metal plate increases the strength of the oscillations induced in the receiver and it is preferably not connected at the end of L because this tends somewhat to damp out the oscillations on short wavelengths. With regard to the design of this model, the author desires to acknowledge the work of Mr. Norman Lea, chiefly in designing the final dimensions of the valve electrodes to give the best results, and that of Messrs. Ree and Bainbridge-Bell in obtaining curves and designing the constants of the oscillatory circuit.

Before concluding, it will be of interest, no doubt, to demonstrate by means of curves the fact that the negatron only oscillates over a given range of filament current. Fig. 6 shows a series of characteristic curves. Main anode current curves are given for different values of filament current. The negative resistance effect disappears completely when the filament current is above 0·575 ampere. Likewise, it disappears, for another reason, when the filament current is very small. An oscillatory circuit will oscillate provided conditions are such as to come within the shaded area, and no difficulty is experienced in practice through the limited range of filament brightness.

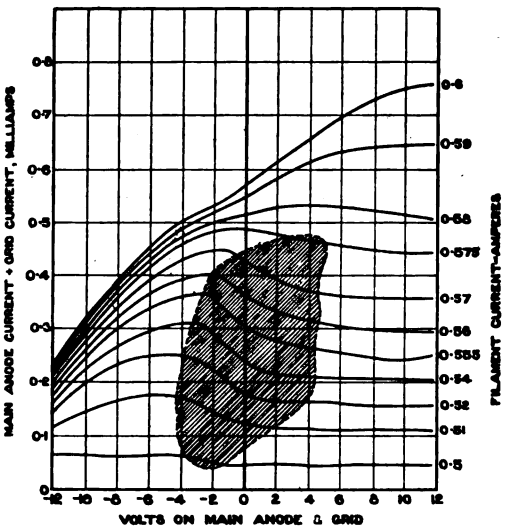

FIG. 6.
(Main anode datum = + 60 V.)

The second negative resistance device, which may be termed a "Biotron," employs two ordinary three-electrode valves, one acting as a conductor of current and the other as a phase-reverser. The valve V_1 (Fig. 7) is the conductor of current from the battery B_2'. Let us imagine an ammeter included across the terminals I N. If the E.M.F. of B_2' were increased we should expect the anode current to be increased. The opposite effect is obtained, however, by arranging that the increase in the anode voltage of V_1 increases the potential of the grid of the valve V_2. The normal potential of this grid is kept near zero by a battery B_3. In the anode circuit of V_2 is an anode battery B_2 and a resistance R. When the grid of V_2 becomes positive, the anode current through R increases, making the grid of V_1 more negative. The battery B_3' keeps the grid of V_1 at a suitable normal potential near zero. By increasing B_2' we therefore have two effects: One is a tendency to produce an increase of anode current by increasing the anode potential; the other is a tendency to decrease the anode current by making the grid more negative. This latter effect greatly outweighs the former, so that the anode current decreases and a negative-resistance characteristic is obtained. If the voltage of B_2' be decreased the converse effect takes place. The circuit, the resistance of which is to be decreased, is normally connected across I N. This static negative-resistance device can produce a very steep negative characteristic. The curve, moreover, is straight. This par-

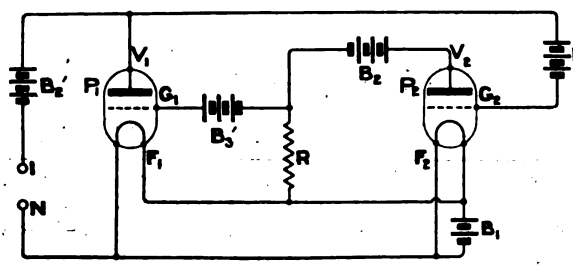

FIG. 7.

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ticular negative resistance bears, at first glance, a certain resemblance to other resistance coupled arrangements, but as far as operation is concerned this is not the case. The arrangement shown in the diagram is perfectly stable. There is no building-up or retroactive action, as in the devices using two anode resistances. In the diagram the "negative-resistance current" does not itself produce any further change in any of the grid potentials. This is not the case with the arrangements the author is thinking of wherein the negative-resistance current passes through a resistance and produces a building-up action. The arrangement is described more fully in *British Patent* 152693 (July 25th, 1919).

Review of Radio Literature.

1. Abstracts of Articles and Patents.*

(C.) Arc Apparatus.

2562. **P. O. Pedersen.** On the Poulsen Arc in Coupled Circuits. (*Proceedings of the Institute of Radio Engineers*, 9, pp. 228—242, June, 1921.)

A mathematical and experimental investigation of the circuit shown in Fig. 1. The results seem to point to the fact that the advantages of applying the shunt circuit (C_1) are not of any great value. (See also p. 569 in this issue.)

2563. **O. C. Roos.** Electromagnetic Wave Transmission System. (*U.S. Patent* 1369281, November 4th, 1918. Patent granted February, 22nd, 1921.)

(F.) Thermionic Valves, and Valve Apparatus.

(4) Design and Construction of Valves.

2564. **J. Niedholt.** An Amplifier for Weak Alternating Currents. (*German Patent* 316408, April 4th, 1917. Patent granted November 25th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, pp. 153—154, February, 1921—Abstract.)

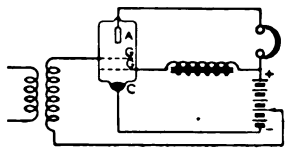

FIG. 2.

A discharge tube filled with one of the rare gases, with a cathode (C) of a substance which has a small cathode-fall in the particular gas. The anode (A) and grids (GG) are connected as shown in Fig. 2.

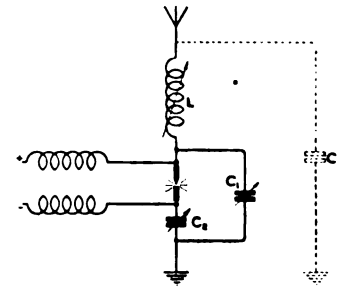

FIG. 1.

2565. **Miss M. Taylor.** Note on the Low Frequency Voltage Factor of an Oscillating Triode. (*Electrician*, 87, pp. 205—206, August 12th, 1921.)

Reference is made to a recent paper by Professor Eccles and Miss Leyshon,† in which the

* Particulars of the U.S.A. Patents abstracted in this section have been supplied by Mr. John B. Brady, Patent Lawyer, Ouray Building, Washington, D.C., U.S.A.; and those of the French Patents by Messrs. J. E. Raworth & Moss, Patent Agents, 75, Victoria Street, London, S.W.

† See RADIO REVIEW Abstract No. 2649.

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voltage factor of a thermionic valve was defined as the change in the anode voltage required to maintain the anode current constant when unit additional E.M.F. is applied between the grid and the filament. This article describes experimental determinations of the voltage factor as defined above in the case of a valve actually generating high frequency oscillations. It is found that in certain circumstances the voltage factor may be much greater than its value when the valve is not oscillating. The results obtained assist in elucidating the action of the auto-heterodyne receiver.

2566. **W. C. Heraeus.** Metals for Vacuum Tube. (*British Patent* 144690, June 9th, 1920. Convention date April 18th, 1918. Patent accepted May 19th, 1921.)

An addition to *British Patent* 138648, describing means for freeing the electrodes of vacuum tubes from the occluded gases.

2567. **H. L. Crowther** and **W. Makower.** Thermionic Valves. (*British Patent* 161115, February 2nd, 1920. Patent accepted April 7th, 1921. *Engineer*, 131, p. 557, May 20th, 1921—Abstract.)

To heat the filament of a thermionic valve it is connected to a low resistance coil inside the bulb, which is excited by induction from a high-frequency current circulating in a coil outside the glass. Alternatively the currents may similarly be induced in a cylindrical cathode.

2568. **Société Anonyme pour l'Exploitation des procédés M. Leblanc-Vickers.** Thermionic Valves; Converting Electric Currents. (*British Patent* 161157, January 24th, 1921. Convention date April 2nd, 1920. Patent not yet accepted.)

Describes the construction of a valve for rectification or oscillation generation.

2569. **S. Loewe.** Thermionic Valves. (*British Patent* 149193, July 12th, 1920. Convention date July 9th, 1918. Patent not yet accepted.)

The cathode of a thermionic valve is made of considerable superficial area, and is rendered incandescent by electric bombardment by giving it a positive potential with respect to an adjacent auxiliary cathode which may comprise a filament heated by a current. The main cathode preferably encloses the auxiliary one.

2570. **S. Loewe** [E. F. Huth Gesellschaft]. Thermionic Valves. (*British Patent* 149210, July 12th, 1920. Convention date March 8th, 1917. Patent not yet accepted.)

Two or more sets of electrodes for use as amplifiers, detectors or oscillation generators are mounted in a single tube.

2571. **K. Rottgardt** and **S. Loewe** [E. F. Huth Gesellschaft]. Thermionic Valves. (*British Patent* 149211, July 12th, 1920. Convention date July 31st, 1919. Patent not yet accepted.)

A thermionic valve has a filament cathode and one or more controlling electrodes so shaped or arranged that the resulting field due to them is uniform in spite of the drop of potential along the cathode, or if preferred the non-uniformity of field due to this cause may be increased, for instance in a valve for use as a detector.

2572. **L. Bischoff** and **S. Loewe** [E. F. Huth Gesellschaft]. Thermionic Valves. (*British Patent* 149238, July 12th, 1920. Convention date March 1st, 1919. Patent not yet accepted.)

Deals with the expulsion of occluded gases from the anodes of valves.

2573. **J. Scott-Taggart.** Thermionic Valves. (*British Patent* 159920, November 6th, 1919. Patent accepted March 7th, 1921.)

For securing the electrode supports of a three-electrode valve U-shaped wires are sealed into the glass stem or walls of the tube and bent down over the electrode supports.

2574. **H. L. Crowther** and **W. Makower.** Thermionic Valve Construction. (*British Patent* 159955, December 4th, 1919. Patent accepted March 4th, 1921.)

During exhaustion of the bulb one or more of the electrodes may be heated by H.F. currents induced from a coil placed outside the tube.

2575. **A. M. Sarnmark.** Thermionic Valves. (*British Patent* 156760, January 7th, 1921. Convention date December 1st, 1919. Patent not yet accepted.)

The valve for oscillation generation is arranged to be simultaneously used as a signalling lamp for visual signalling.

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2576. **L. A. McDougald.** Thermionic Valves. (*British Patent* 158011, July 28th, 1919. Patent accepted February 3rd, 1921.)

In a valve for use as a continuous-wave generator for wireless signalling, the anode, or a plate to which the anode is attached, forms part of the wall of a glass bulb, and of a glass reservoir containing cooling liquid, the anode and the reservoir being connected by fusion with the bulb.

2577. **S, R, Mullard.** Thermionic Valves. (*British Patent* 158720, November 14th, 1919. Patent accepted February 14th, 1921.)

Deals with an arrangement of sealing tube or support for the valve electrodes such that the electrodes may be readily replaced, while at the same time a long leakage path is provided between the electrode supports. (See also pp. 537—544 in last issue.)

2578. **Gesellschaft für drahtlose Telegraphie.** Electric Discharge Apparatus. (*British Patent* 147441, July 7th, 1920. Convention date January 29th, 1918. Patent not yet accepted.)

A cathode for a "cathode tube" is formed of a metal of the alkaline-earth group such as calcium or magnesium. The tube may contain hydrogen or one of the rare gases.

2579. **Gesellschaft für drahtlose Telegraphie.** Thermionic Valves. (*British Patent* 147443, July 7th, 1920. Convention date October 10th, 1918. Patent not yet accepted.)

In a valve for use as an oscillation generator the cathode is heated by discharge from an auxiliary filament cathode placed behind it, a high potential being maintained between the cathodes.

2580. **Gesellschaft für drahtlose Telegraphie.** Thermionic Valve Apparatus. (*British Patent* 147463, July 7th, 1920. Convention date February 9th, 1915. Patent not yet accepted.)

Relates to the use of an alkaline metal or alloy for the cathode of a thermionic amplifying tube.

2581. **I. Langmuir** [British Thomson-Houston Co.]. Thermionic Valves. (*British Patent* 147616, July 8th, 1920. Convention date October 16th, 1913. Patent not yet accepted.)

A hard three-electrode tube of the "pliotron" type.

2582. **H. St. J. de A. Donisthorpe.** Thermionic Valves. (*British Patent* 162338, December 23rd, 1919. Patent accepted. *Engineer*, 131, p. 631, June 10th, 1920—Abstract.)

A valve in which the grid and plate are in the form of hollow hemispheres enclosing the loop filament. Greater rigidity is claimed. (See RADIO REVIEW, 2, p. 431, August, 1921, for illustration of this valve.)

2583. **A. K. Macrorie, C. L. Fortescue, G. B. Bryan** and **H. Morris-Airey.** Thermionic Valves. (*British Patent* 162367, January 23rd, 1920. Patent accepted April 25th, 1921.)

A transmitting valve with a metal casing forming the anode, provided with a pump for maintaining the vacuum and arranged for easy opening to renew the electrodes. The metal container may be artificially cooled.

2584. **G. Seibt.** Thermionic Valves. (*British Patent* 147043, July 6th, 1920. Convention date October 24th, 1913. Patent not yet accepted.)

Relates to a valve having a double cone-shaped grid to which the incoming oscillations are applied. The arrangement is similar to that sketched on p. 1, January, 1921, RADIO REVIEW. A slotted plate anode may be used having the slots in line with the spaces between the teeth of the comb-like grids.

2585. **E. F. Huth.** Thermionic Valves. (*British Patent* 148314, July 9th, 1920. Convention date March 30th, 1918. Patent not yet accepted.)

Relates to the introduction of small quantities of gas or vapour (such as ether) during exhaustion, so as to increase the normal anode current.

2586. **O. Kruh.** Sealing Electric Conductors in Glass Vessels. (*British Patent* 148522, July 10th, 1920. Convention date January 15th, 1919. Patent not yet accepted.)

2587. **Gesellschaft für drahtlose Telegraphie.** Thermionic Valves. (*British Patent* 148525, July 10th, 1920. Convention date April 30th, 1919. Patent not yet accepted.)

Deals with the structural design of the valve to secure the generation of oscillations with the minimum of reaction coupling.

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2588. **Electrische Gluhlampenfabrik Watt Akt. Gesellschaft.** Vacuum Tubes. (*British Patent* 152617, October 16th, 1920. Convention date October 18th, 1919. Patent not yet accepted.)

Relates to special means of sealing the electrodes into glass.

2589. **A. K. Macrorie** and **H. Morris-Airey.** Thermionic Valves. (*British Patent* 162773, February 2nd, 1920. Patent accepted May 2nd, 1921.)

Two- or three-electrode valves have an additional anode, preferably in the form of a grid, and connected externally to the main anode through an energy-absorbing resistance or similar device. The heating of the main anode is thus reduced.

2590. **E. R. Stoekle.** Thermionic Valves. (*British Patent* 146357, July 2nd, 1920. Convention date June 13th, 1917. Patent not yet accepted.)

Relates to thermionic valves in which the cathode is heated by an auxiliary electronic bombardment.

2591. **R. A. Weagant** [Radio Corporation, U.S.A.]. Thermionic Valves. (*British Patent* 146529, July 5th, 1920. Convention date April 5th, 1915. Patent not yet accepted.)

Relates to a thermionic valve in which the control member is outside the glass.

2592. **R. A. Weagant** [Radio Corporation, U.S.A.]. Thermionic Valves. (*British Patent* 146531, July 5th, 1920. Convention date April 5th, 1915. Patent not yet accepted.)

A thermionic valve with an external control electrode is provided in addition with a disconnected interior grid.

2593. **R. A. Weagant** [Radio Corporation, U.S.A.]. Thermionic Valves. (*British Patent* 146533, July 5th, 1920. Convention date April 2nd, 1915. Patent not yet accepted.)

Relates to connection schemes for a thermionic valve with external grid. (See two preceding Abstracts.)

2594. **Naamlooze Vennootschap Philips Gloeilloeilampenfabrieken**; **M. G. Holst** and **E. Oosterhuis.** Valve Construction. (*French Patent* 507519, December 18th, 1919. Published September 17th, 1920.)

The specification describes an anode for a thermionic oscillation generator. The anode is made hollow so that the inside is accessible from without. Water and gas may be passed through the interior and during exhaustion a heater may be inserted to expel the gases. See also *British Patent* 137281 (Radio Review Abstract No. 797, September, 1920).

2595. **R. A. Weagant** [Radio Corporation, U.S.A.]. Thermionic Valves. (*British Patent* 146537, July 5th, 1920. Convention date March 10th, 1917. Patent not yet accepted.)

Constructional details for a valve with external control electrode.

2596. **R. A. Weagant** [Radio Corporation, U.S.A.]. Thermionic Valves. (*British Patent* 146538, July 5th, 1920. Convention date March 10th, 1917. Patent not yet accepted.)

Relates to a guard ring construction to remove static charges from the glass bulb.

2597. **R. A. Weagant** [Radio Corporation, U.S.A.]. Thermionic Valve Construction (*British Patent* 146539, July 5th, 1920. Convention date February 1st, 1916. Patent not yet accepted.)

2598. **R. A. Weagant** [Radio Corporation, U.S.A.]. Thermionic Valves. (*British Patent* 146540, July 5th, 1920. Convention date February 1st, 1916. Patent not yet accepted.)

Relates to a Fleming two-electrode valve with a connection to the hottest point on the filament.

2599. **Siemens** and **Halske Akt. Gesellschaft.** Thermionic Valves. (*British Patent* 145421, June 17th, 1920. Convention date May 31st, 1916. Patent not yet accepted.)

A thermionic valve has an incandescent cathode, a grid, an anode, and an openwork electrode interposed between the grid and the anode and maintained at a constant potential lower than that of the anode.

2600. **J. Scott-Taggart.** Thermionic Valves. (*British Patent* 146708, June 20th, 1919. Patent accepted July 15th, 1920.)

Relates to a double anode rectifying valve in which the two anodes have opposite polarities at any given instant.

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2601. Wireless Inventions. (*Journal of Commerce*, June 29th, 1921.)
An account of a demonstration by **R. M. Radio, Ltd.**, of a new pattern of triode valve having a hemispherical anode and grid.*

2602. **L. Duverger.** Electric Signalling and Transmission Systems. (*British Patent* 157385, January 10th, 1921. Convention date February 16th, 1918. Patent not yet accepted.)
A method of transmitting telephone or power currents over a single wire without an earth return. A device termed an " absorbing apparatus " is employed, consisting of a metal tube containing an oxide-coated filament and a grid. Gas may be passed through the tube by appropriate stopcocks.

2603. **O. Durdle** [General Electric Co., London]. Thermionic Valves. (*British Patent* 156411, January 2nd, 1920. Patent accepted January 13th, 1921.)
The support for the loop of a valve filament is made of steatite, as it is stated that this material does not occlude gases.

2604. **C. F. Trippe** [General Electric Co., London]. Thermionic Valves. (*British Patent* 151462, September 12th, 1919. Patent accepted September 30th, 1920.)
Relates to caps for valves.

2605. **E. Schaeffer** [Franklin Industrie Gesellschaft]. Vacuum Tubes. (*British Patents* 153002 and 153003, October 25th, 1920. Convention dates August 26th and October 24th, 1919. Patents not yet accepted.)
A construction for vacuum tubes, applicable to thermionic valves, in which one of the electrodes is in the form of a conducting liquid on the outside of the glass or other container.

2606. **J. Scott-Taggart.** Thermionic Valves. (*British Patent* 154364, September 8th, 1919. Patent accepted December 2nd, 1920.)
To reduce the space charge in a valve an element of perforated metal work is mounted inside the anode and connected to it.

2607. **W. Kossel.** Thermionic Valves. (*British Patent* 147856, July 9th, 1920. Convention date December 23rd, 1916. Patent not yet accepted.)
A magnetic field is used for controlling the discharge in a thermionic valve. The magnet may be sealed inside the bulb.

2608. **O. Kruh.** Sealing Electric Conductors through Glass. (*British Patent* 148127, July 9th, 1920. Convention date July 6th, 1917. Patent not yet accepted.)

2609. **I. Langmuir** [British Thomson-Houston Co.]. Electron Discharge Devices. (*British Patent* 148130, July 9th, 1920. Convention date June 6th, 1914. Patent not yet accepted.)
The anode of a thermionic valve is deposited on the bulb by vaporisation of the metal in a vacuum.

2610. **I. Langmuir** [British Thomson-Houston Co.]. Electron Discharge Devices. (*British Patent* 148132, July 9th, 1920. Convention date October 28th, 1915. Patent not yet accepted.)
The filament of the valve is made of thorium, and potassium or other alkali metal is placed in the tube to prevent oxidation of the thorium.

2611. **W. Kossel.** Electron Discharge Apparatus. (*British Patent* 148184, July 9th, 1920. Convention date March 1st, 1917. Patent not yet accepted.)
Relates to a valve in which the cathode is heated by auxiliary ionic bombardment.

2612. **J. Marsten.** The Efficient Design of Vacuum Tube Telegraph and Telephone Sets. (*Radio News*, 2, pp. 870—871, June, 1921 ; pp. 23 and 48—59, July, 1921.)
Some data is given for the design of the circuits to obtain the most efficient operation.

2613. **General Electric Company, U.S.A.** [British Thomson-Houston Co., Ltd.]. Thermionic Valves. (*British Patent* 163745, January 12th, 1920. Patent accepted May 12th, 1921.)
A two-electrode thermionic valve, which may or may not contain gas, having a " negative

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* See also RADIO REVIEW Abstract No. 2582.

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resistance," the current between the electrodes varying inversely as the potential applied thereto. The characteristic curve is as shown in Fig. 3.

2614. **S. S. Torissi.** A New Cathode for Vacuum Tubes. (*Wireless Age*, 8, p. 23, August, 1921.)

The proposed cathode consists of a nickel cylinder heated by an internal filament.

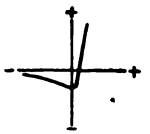

FIG. 3.

2615. **J. B. Pratt** [General Electric Company]. Degasifying Process for Valves. (*U.S. Patent* 1374679, March 15th, 1920. Patent granted April 12th, 1921.)

(5) TESTS AND MEASUREMENTS ON VALVES AND VALVE CIRCUITS.

2616. **Gesellschaft für drahtlose Telegraphie.** Valve Vacuum Tester. (*German Patent* 316448, February 14th, 1918.)

A circuit for measuring the positive ionisation in a valve. The grid is made positive with respect to the filament while the usual anode battery is reversed. The positive ions are detected by means of a galvanometer in the anode circuit.

2617. **F. Holborn.** New Experiments with the Dynatron. (*Telegraphen- und Fernsprech-Technik*, 10, pp. 1—10, January—February; pp. 17—22, March, 1921.)

An oscillographic investigation of an ordinary three-electrode valve used as a dynatron to maintain oscillations of a frequency of 20 cycles per second. The static dynatron characteristics of the valves are also given and the dynamic results are found to agree with the static. The distortion of the anode current at each limit of its amplitude is studied for various conditions. The gradual building up of an oscillation is shown on oscillograph films both for the dynatron circuit and for the ordinary back-coupled valve circuit.

2618. **L. Hartshorne** and **E. S. Keeping.** Notes on Vacuum Tubes used as Detectors of Electric Oscillations. (*Proceedings of the Physical Society of London*, 33, pp. 249—258, June 15th, 1921. *Chemical News*, 122, pp. 259—260, June 3rd, 1921—Abstract; *Nature*, 107, pp. 445—446, June 2nd, 1921—Abstract.)

Describes experiments on neon-filled tubes used as detectors in aircraft wireless sets.

2619. **F. F. Martens.** Alternating Current Measurements on Amplifying Valves. (*Zeitschrift für Physik*, 4, pp. 437—440, 1921.)

A.C. methods of determining the internal resistance R_i and the amplification ratio $1/D$ have been described by Barkhausen, Miller and Schottky, but these all assume zero grid current; this assumption is not made in the present methods, which are A.C. bridge methods.

Fig. 4 shows the connections for finding D and Fig. 5 those for finding R_i. When silence is obtained in the telephone receiver T it is shown that in Fig. 4 $D = l/r$, and in Fig. 5 $R_i = \frac{1+D}{D} \cdot \frac{l}{r} \cdot R$.

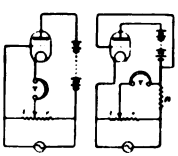

FIG. 4. FIG. 5.

2620. **H. de A. Donisthorpe.** The Testing of Thermionic Triodes. (*Model Engineer*, 45, pp. 119—120, August 11th, 1921.)

Describes insulation, backlash and other tests on valves.

(6) APPLICATION OF VALVES TO OSCILLATION GENERATION (including Valve Transmitting Apparatus).

2621. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Continuous Wave Transmitter. (*French Patent* 506986, May 14th, 1919. Published September 2nd, 1920.)

The inductances of the plate and grid circuits of a vacuum tube oscillation generator are connected in series in the aerial circuit whereby the aerial-earth capacity forms an electrostatic coupling between the plate and grid circuits. The amplitude of the oscillations may be controlled by applying potential variations of audible frequency to the grid, such variations being amplified by the tube and returned to the grid circuit by a transformer. See also *British Patent* 127325 (RADIO REVIEW Abstract No. 13, October, 1919).

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2622. **Gesellschaft für drahtlose Telegraphie.** Short Wave Generator. (*German Patent* 305063, October 21st, 1917. Patent granted January 29th, 1920. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 309, October, 1920—Abstract.)

A generator (see Fig. 6) in which the internal capacities of the valve are used as coupling.

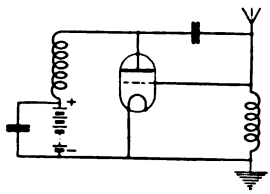

Fig. 6.

2623. **H. G. Möller.** The Theory of the Phase Reversal in Coupled Oscillatory Valve Circuits. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 402—431, December, 1920. *Radioélectricité*, 2, p. 130, August, 1921—Abstract.)

A mathematical and experimental investigation of the phenomena observed when an oscillatory circuit is coupled to the oscillatory anode circuit and the frequency of the former varied through the resonance value. The method of treatment is that of the "phase-balance," *i.e.* if a current in the anode circuit produces by reaction through the back-coupling and grid an anode current lagging behind the assumed initial current, the frequency will decrease and *vice versâ* until a balance is obtained. A simple graphical method is evolved for determining the amplitude and frequency-resonance curves. The values of the critical coupling are calculated for various values of damping and frequency; the frequency-resonance curve and the position of the reversal point are determined by calculation and the results compared with the experimental results. Good agreement is found.

2624. **L. A. Hazeltine.** Valve Oscillators for Radio Transmitters. (*Proceedings of the Radio Club of America*, 1, pp. 2—10, October, 1920. *Q.S.T.*, 4, pp. 5—8, October, and pp. 15—19, November, 1920.)

Paper read before the Radio Club of America. Various arrangements of oscillating valve are discussed together with a consideration of the mode of operation of such transmitters from the characteristic curve of the valves. The circuit designed for best operation is also given and the paper concludes with an arrangement of polyphase oscillators.

2625. Self-rectifying C. W. Sets. (*Q.S.T.*, 4, pp. 7—10, December, 1921.)

A description is given of valve transmitting sets for operation on A.C. using one or both half-waves of the A.C. supply. Some particulars are given as to constructional details of a 500 watt set built on these lines.

2626. **Société Indépendante de Télégraphie sans Fil.** Wireless Transmitting and Receiving Apparatus. (*British Patent* 153553, May 4th, 1920; Convention date May 5th, 1919. Patent not yet accepted.)

In a valve oscillation generator a relay valve is used to couple the variations of the plate potential of the oscillating valves back to their grids. By slight alterations of the connections the arrangement can alternatively be used as a receiver.

2627. **W. Hyndman.** Short Wave Radio Vacuum Tube Transmitter and Regenerative Reception with Two-Step Audio-Frequency Amplifier. (*Radio News*, 2, p. 693, April, 1921.)

2628. **J. Marsten.** The Use of A.C. Potential with Vacuum Tube Transmitters. (*Radio News*, 2, pp. 604—605, March, 1921. *Radioélectricité*, 2, p. 13D, August, 1921.)

After summarising some of the usual buzzer methods of radiating interrupted C.W. the author discusses the advantages to be obtained by operating the transmitting valve on an alternating current supply.

2629. **Compagnie Française pour l'Exploitation des Procédés Thomson-Houston.** Continuous Wave Transmitter. (*French Patent* 507651, December 23rd, 1919. Published September 21st, 1920.) Also **I. Langmuir** [British Thomson-Houston Co.]. (*British Patent* 144647, June 7th, 1920. Convention date October 29th, 1913. Patent not yet accepted.)

The specification describes arrangements for the production of oscillations of any frequency from direct current or alternating current, by employing an electron discharge tube in which

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the grid-filament and anode-filament circuits are coupled by external electro-magnetic or electrostatic couplings or by the capacity between the electrodes. Several examples of arrangements are given.

2630. **L. M. Clausing.** Interrupted Continuous Waves from 60 Cycle Current. (*Q.S.T.*, 4, pp. 5—6, February, 1921.)

A commutator arrangement is described for interrupting the power supply to a valve transmitter, the energy being derived from 60 cycle A.C. mains.

2631. **F. Harms.** Triode Oscillation Generators with Coupled Oscillatory Circuits. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, p. 218, March, 1921.)

A correction to the article with the above title. See RADIO REVIEW, 2, pp. 313—322, June, 1921, and footnote on p. 315.

2632. **K. Heegner.** Valve Transmitters with Coupled Oscillatory Circuits. (*Archiv für Elektrotechnik*, 9, pp. 127—152, 1920. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, pp. 133—137, February, 1921—Abstract.)

An abstract by the author of his Jena dissertation of July, 1919. It is an analytical investigation of the valve transmitter with coupled oscillatory circuits.

2633. **Gesellschaft für drahtlose Telegraphie.** Thermionic Oscillation Generators. (*British Patent* 148991, July 12th, 1920. Convention date August 7th, 1917. Patent not yet accepted.)

In methods of generating oscillations with thermionic valves, the aerial is coupled with the grid oscillatory circuit in such a way that the latter is uninfluenced by the varying factors of the former. Suggested arrangements for this purpose are indicated in Fig. 7.

2634. **W. H. Eccles** and **F. W. Jordan.** Thermionic Valve Oscillation Generators. (*British Patent* 149018, March 20th, 1918. Patent accepted August 12th, 1920.)

Deals with the use of the valves in parallel for generating oscillations. For description of the arrangements see RADIO REVIEW, 1, pp. 80—83, November, 1919.

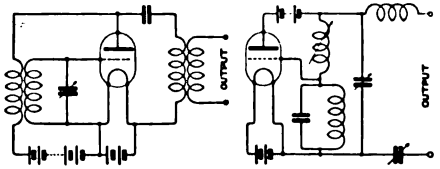

FIG. 7.

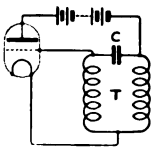

FIG. 8.

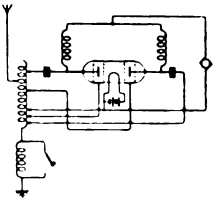

FIG. 9.

2635. **W. Heller** [E. F. Huth Gesellschaft]. Thermionic Valve Oscillation Generators. (*British Patent* 149192, July 12th, 1920. Convention date July 17th, 1918. Patent not yet accepted.)

Describes a number of arrangements of the circuits of thermionic valves for generating or amplifying H.F. oscillations.

2636. **S. Loewe** [E. F. Huth Gesellschaft]. Producing Electric Oscillations. (*British Patent* 149195, July 12th, 1920. Convention date July 16th, 1917. Patent not yet accepted.)

An arrangement of valve oscillator particularly adapted to the production of short waves. See Fig. 8. The coils T may if desired be in the form of an autotransformer. For reception the circuit joined by T and C may be detuned to produce beats, the receiving circuit being coupled to T.

2637. **C. L. Farrand** [Radio Corporation of America]. Radio Transmitter. (*U.S. Patent* 1385818, June 14th, 1919. Patent granted July 26th, 1921.)

A vacuum tube is arranged with a plurality of external control members outside of the tube connected in separate circuits. Oscillations are produced in the several circuits and energise the antenna system (Fig. 9).

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2638. **V. J. F. Bouchardon.** Generator of High-frequency Oscillations for Wireless Telegraphy. (*U.S. Patent* 1373710, October 24th, 1919. Patent granted April 5th, 1921.)
See corresponding *British Patent* 135464 (RADIO REVIEW Abstract No. 409, June, 1920) and *French Patent* 493222 (RADIO REVIEW Abstract No. 107, January, 1920).

(G.) Transmitter Control or Modulation.

2639. **F. Ware** [Ware Radio Inc.]. Cut-in System of Radio Telegraphy. (*U.S. Patent* 1379144, February 8th, 1918. Patent granted May 24th, 1921.)

2640. **C. R. Englund** [American Telephone and Telegraph Company]. Radiotelephony. (*U.S. Patent* 1258548. Re-issue No. 15089, March 3rd, 1920. Re-issue granted April 19th, 1921.)

2641. **H. D. Arnold** [Western Electric Company]. Power Modulator for Radio-Transmission. (*U.S. Patent* 1375481, August 23rd, 1915. Patent granted April 19th, 1921.)

2642. **D. C. McCaa** [Assigned one-half to C. D. Ehret]. Transmitting Apparatus. (*U.S. Patent* 1382206, May 10th, 1920. Patent granted June 28th, 1921.)
Transmitting apparatus, for radiotelephony in which the high-frequency energy is not present in the antennæ and ground system until the microphone is operated. The carrier frequency oscillations are generated by vacuum tube and controlled by a microphone such that instantly the voice or sound waves cease at the microphone the high-frequency energy ceases in the antenna system and similarly instantly sound waves or speech are initiated and continued at the microphone oscillations are present in the antenna system and vary in accordance with the speech.

2643. **R. A. Heising** [Western Electric Company]. Power Modulator for Radio Transmission. (*U.S. Patent* 1383807, September 21st, 1915. Patent granted July 5th, 1921.)
The modulation of the total high-frequency power is obtained by varying the impedance of a vacuum tube placed in the antenna circuit. In order to permit the passage of both halves of the high-frequency oscillations the system is made symmetrical by using two vacuum tube impedances, suitably connected, or by using a single vacuum tube impedance containing additional elements which render the circuit symmetrical.

2644. **E. F. W. Alexanderson** [General Electric Company]. Method of and Apparatus for Producing and Distributing Electric Current Waves of Radio Frequency. (*U.S. Patent* 1386830, August 5th, 1915. Patent granted August 9th, 1921.)
Two sources of radio frequency circuits are impressed upon the transmitting aerial, so that their resultant only is radiated.

2645. **H. E. Shreeve** [Western Electric Company]. Signalling System. (*U.S. Patent* 1378982, September 17th, 1918. Patent granted May 24th, 1921.)

(H.) Radio Receiving Apparatus.

2646. **J. Kunz** [Board of Trustees of the University of Illinois]. Photo-electric Cell, Method and Means for Making the Same. (*U.S. Patent* 1381474, August 24th, 1918. Patent granted June 14th, 1921.)

2647. **T. W. Case.** Radio Receiver. (*U.S. Patent* 1379167, February 20th, 1918. Patent granted May 24th, 1921.)

2648. **C. Bardeloni.** Device for Receiving Radio Telegraphic and Radio Telephonic Signals. (*U.S. Patent* 1381692, April 12th, 1919. Patent granted June 14th, 1921.)

2649. **W. H. Eccles and Miss W. A. Leyshon.** Some Thermionic Tube Circuits for Relaying and Measuring. (*Journal of the Institution of Electrical Engineers*, 59, pp. 433—438, April, 1921; *Electrical Review*, 88, p. 354, March 18th, 1921; *Technical Review*, 9, p. 111, May 17th, 1921—Abstract; *Electrician*, 86, pp. 754—755, June 17th, 1921—Abstract.)
Paper read before the Wireless Section of the Institution of Electrical Engineers and discussion. See RADIO REVIEW, 2, pp. 169—170, April, 1921, for abstract of paper.

2650. **A. W. Hull** [General Electric Company]. Wireless Receiving System. (*U.S. Patent* 1387986, March 10th, 1917. Patent granted August 16th, 1921.)
Wireless receiving system, employing a negative resistance device connected to the radio

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frequency receiving circuit for reducing the damping thereof. The negative resistance device is connected to the oscillating circuit in such a way as to compensate for the positive resistance of the circuit reducing the damping factor and increasing the maximum possible amplification of the oscillations in the circuit.

2651. **R. V. L. Hartley** [Western Electric Company]. Receiving Apparatus for Wave Signalling. (*U.S. Patent* 1387262, September 30th, 1915. Patent granted August 9th, 1921.)

Receiving apparatus for wave-signalling, which may be readily changed to receive telephonic and telegraphic signals either with or without the heterodyne. A local generator at the receiver may be cut in or removed from the circuit to permit reception by means of the heterodyne or by straight rectification and amplification of the signals.

2652. **R. E. Hall** [Hall Research Corporation]. Method of and Means for Translating Energy Variations. (*U.S. Patent* 1378345, May 31st, 1919. Patent granted May 17th, 1921.)

(K.) Aerials and Earthing Systems.

2653. **S. C. Hooper** and **G. H. Clark.** Radio Receiving Antenna. (*U.S. Patent* 1379262, September 16th, 1919. Patent granted May 24th, 1921.)

2654. **H. H. Beverage** [General Electric Company]. Radio Receiving System. (*U.S. Patent* 1381089, April 10th, 1920. Patent granted June 7th, 1921.)

2655. **E. T. Jones.** Underground or Underwater Antenna System. (*U.S. Patent* 1372658, April 11th, 1919. Patent granted March 22nd, 1921.)

See Radio Review Abstract No. 378, May, 1920.

2656. **E. C. Hanson.** Underground Loop Antenna. (*U.S. Patent* 1373612, March 19th, 1919. Patent granted April 5th, 1921.)

2657. **A. A. Hall.** Wireless Signalling Apparatus. (*U.S. Patent* 1384523, November 1st, 1919. Patent granted July 12th, 1921.)

Wireless signalling apparatus, comprising an oscillating vacuum tube transmitter wherein the oscillatory circuit is completed through a portion of the earth. See corresponding *French* and *British Patents* (Radio Review Abstract No. 1700, April, 1921).

2658. **J. H. Rogers.** Radio Signalling System. (*U.S. Patent* 1387736, May 2nd, 1917. Patent granted August 16th, 1921.)

Radio signalling system for operation aboard submarine vessels. An antennæ is employed, comprising horizontal wires disposed entirely within the metallic hull of the vessel with a metallic screen enclosing the antennæ throughout their length.

2659. **E. F. W. Alexanderson** [General Electric Company]. Radio Receiving System. (*U.S. Patent* 1375992, April 18th, 1919. Patent granted April 26th, 1921.)

2660. **H. H. Beverage** [General Electric Company]. Radio Receiving System. (*U.S. Patent* 1381089, April 10th, 1920. Patent granted June 7th, 1921.)

A horizontal and aperiodic antenna extending in a direction parallel to the direction of transmission of the signals to be received is used. The antenna is constructed with distributed capacity, inductance and resistance of such values that the currents produced therein by the desired signals increase progressively from the end of the antenna nearest the transmitting station to a maximum at the farthest end from the transmitting station at which the receiver is connected.

(P.) High-frequency Circuits and Measurements.

2661. **E. T. Turney.** Inductances. (*U.S. Patent* 1372850, April 1st, 1920. Patent granted March 29th, 1921.)

2662. **J. S. E. Townsend.** Variometer. (*U.S. Patent* 1376592, April 10th, 1918. Patent granted May 3rd, 1921.)

2663. **A. M. Curtis** [Western Electric Company]. Construction of Reaction Coils. (*U.S. Patent* 1367734, August 16th, 1917. Patent granted February 8th, 1921.)

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2664. **C. D. Tuska.** Condenser. (*U.S. Patent* 1371061, March 29th, 1918. Patent granted March 8th, 1921.)

2665. **H. W. Hitchcock** [American Telephone and Telegraph Company]. Electrical Measuring Apparatus. (*U.S. Patent* 1373504, September 11th, 1918. Patent granted April 5th, 1921.)

2666. **E. Thompson** [General Electric Company]. Condenser. (*U.S. Patent* 1375982, November 16th, 1916. Patent granted April 26th, 1921.)

2667. **F. Kratz** [American Bosch Magneto Corporation]. Electrical Condenser and Method of Making It. (*U.S. Patent* 1385379, January 26th, 1917. Patent granted July 26th, 1921.)

Electrical condenser and method of making it. The condenser is constructed upon an oval core with alternate bands of foil and dielectric wound thereon, the individual bands having laterally projecting edge portions lying flat against the opposite sides of the condenser to form side terminals.

(U.) Miscellaneous Methods of Communication.

2668. **T. W. Case.** Radiant Energy Signalling System. (*U.S. Patent* 1379166, January 22nd, 1918. Patent granted May 24th, 1921.)

2669. **R. A. Fessenden** [Submarine Signal Company]. Method and Apparatus for Signalling and otherwise Utilising Radiant Impulses. (*U.S. Patent* 1384014, January 14th, 1918. Patent granted July 5th, 1921.)

Method and apparatus for signalling and otherwise utilising radiant impulses, in which a tetrahedron collector, having three joining faces at right angles to each other and another surface in proximity to the tetrahedron is employed whereby the incidence of radiant energy on the tetrahedron may be determined. The system employs light waves, heat waves, ultra-violet waves, X-rays, Hertzian waves, or sound waves.

2670. **L. Bell** and **N. Marshall.** Method of and Apparatus for Utilisation of Observable Radiations. (*U.S. Patent* 1385657, February 1st, 1919. Patent granted July 26th, 1921.)

Method of and apparatus for utilisation of observable radiations. Signalling is conducted by use of invisible light rays by forming a directive beam of rays between 400 $\mu\mu$ and 350 $\mu\mu$ wavelength and by collecting the rays for observation on a fluorescent medium.

2671. **N. Marshall** and **L. Bell.** Method of and Apparatus for Utilisation of Observable Radiations. (*U.S. Patent* 1385696, February 1st, 1919. Patent granted July 26th, 1921.)

Method and apparatus for utilisation of observable radiations. A combined transmitting and receiving apparatus is provided for communication by light rays, comprising at the receiver an observing objective lense and an eye piece and fluorescent medium acted upon by invisible rays; and at the transmitter a projector of rays.

2672. **W. G. Ziegler.** Submarine Wireless System. (*U.S. Patent* 1382590, January 3rd, 1920. Patent granted June 21st, 1921.)

Submarine wireless system, operating at low frequencies. The patent discloses a particular form of transmitting and receiving apparatus.

2673. **W. W. Macfarlane.** System of Communication. (*U.S. Patent* 1370333, May 15th, 1919. Patent granted March 1st, 1921.)

2. Books.

PRINCIPLES OF RADIO COMMUNICATION. By J. H. Morecroft (Assistant Professor of Electrical Engineering, Columbia University), assisted by A. Pinto and W. A. Curry. (New York: *John Wiley & Sons, Inc.* London: *Chapman and Hall, Ltd.*, 1921. Pp. x + 935. 9″ × 6″. Price 45s. net.)

Although the literature of wireless telegraphy (or Radio, as our American friends prefer to call it) has become quite voluminous in recent years, the development of the subject has

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never failed to outstrip its literature, so that there is ample room for a modern treatise of the character of this work, viz., a general text-book for the use of both students and wireless engineers.

Time was when books on wireless telegraphy generally began with what purported to be an explanation of the ether (from which the student might sometimes learn that it was both imponderable and luminiferous) and it is symptomatic of the times that the present author plunges at once into a discussion on electrons and gives no more than a passing reference to the elastic properties of the medium. In these circumstances a brief description of the physical experiments upon which the theory rests would not have been out of place, though no fault can be found with the way the electron is treated. In this treatment the presence of a positive charge is rightly dealt with as the absence of negative electrons, just as cold is the absence of heat; but the statement (p. 8) "the smallest positive charge is an atom of matter from which an electron has been removed" (which would be equally true if a gramme was substituted for an atom) might lead the student to suppose that he had met the positive nucleus.

Throughout the book the author has dealt fully with the various electrical problems that arise, not shunning or overdoing their mathematical treatment on the one hand, nor failing to give a physical concept of each equation on the other. But the mathematical treatment is not always equally detailed. For example in Chapter IV. the derivation of Kelvin's equation for the current produced by the discharge of a condenser is given in full (though it is inaccurate to describe the substitution of e^{mt} for i in the solution of a linear differential equation of the second order as an "intelligent guess"), while later on in the same chapter (p. 221) we are told that a damped sine may be integrated by standard methods, and are given the solution forthwith. It might be useful to the student, as well as to the engineer seeking to refresh his memory, to be at least reminded that the sine must be split up into exponentials.

Vacuum tubes are very well treated in Chapter VI., which should prove very useful to all interested in the subject, though the hydraulic model of the three-electrode valve (p. 386) is not nearly as good as the model exhibited by Mr. Gossling at the meeting of the Wireless Section of the Institution of Electrical Engineers on June 23rd, 1920.

Continuous wave telegraphy and radiotelephony are also very well treated in Chapters VII. and VIII. respectively.

A chapter which is conspicuous by its absence from a work of this nature is that generally entitled "Historical," but the author is no doubt wise in avoiding everything of a controversial character and in giving no grounds for an accusation of bias.

The figures and printing are good, and the small errors inseparable from a first edition not too numerous, while with the exception of "neighbor" and "center" the spelling is English.

Taken altogether the book fulfils its title and should prove valuable to every one engaged in wireless telegraphy.

J. S. V. P.

Correspondence.

THE FOUR FUNCTIONAL PARAMETERS OF THE TRIODE AS EXTENDED TO THE "MAGNETRON."

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In French Patent No. 512295 of April 15th, 1916, as well as in an article which appeared on page 280, volume 78, of the *Electrician* for 1916, the writer has introduced the four well-known functional parameters of the triode, $\frac{\partial i_p}{\partial v_p}, \frac{\partial i_p}{\partial v_g}, \frac{\partial i_g}{\partial v_g}, \frac{\partial i_g}{\partial v_p}$, the use of which has become classic.

It has recently occurred to the author to ascertain what became of these four parameters with reference to the vacuum tube designated by Mr. A. W. Hull under the name of "magnetron" (see *Proceedings of the American Institute of Electrical Engineers*, September,

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1921), and in which the electrostatic grid control of the electron stream is replaced by an outside coil producing a magnetic field.

This particular tube, in which it is necessary to superimpose a permanent field to the controlling field in order to obtain practical results, has already been described as detector, amplifier and generator in the French Patent No. 503935, 1917, of Messrs. Bouchardon and Lesage.

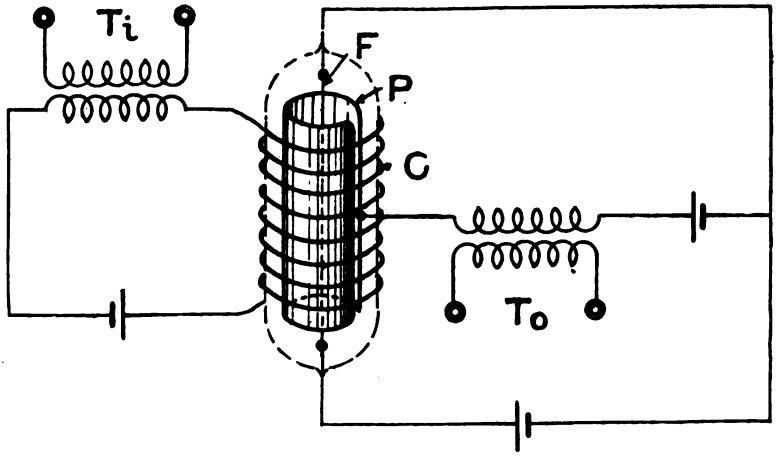

FIG. 1.

The magnetron, as represented in Fig. 1, comprises an axial filament, F, a cylindrical anode, P, and an outside coil, C, which is traversed by the current to be amplified and a permanent direct current. Fig. 1 illustrates the input transformer, T_i, and the output transformer, T_0.

The anode current, i_p, is a function of the anode potential, v_p, and of the total current, i, which traverses the coil, C. We have $i_p = F(v_p, i)$, whence there results two parameters for the plate current, $\frac{\partial i_p}{\partial v_p}$, $\frac{\partial i_p}{\partial i}$, similar to those of the triode.

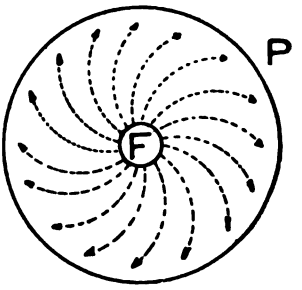

FIG. 2.

But the method of deriving *two* parameters for the control circuit is not readily apparent. They nevertheless exist. If we consider the case of the triode with an electrostatic grid, the fourth parameter, $\frac{\partial i_g}{\partial v_p}$, generally approximates zero. From a theoretical point of view, however, this parameter is of great importance, for it defines the possible reaction of the plate circuit upon the grid circuit.

Might there also be a similar reaction of the plate circuit upon that of the coil, C, in the case of the magnetron? In fact, there might be one. While the electrons are being whirled around the filament, as shown in Fig. 2, they tend to produce a magnetic field parallel to the axis of the filament and consequently that of the coil, C, and the flux embraced by the latter actually includes the flux produced by that field. In this case, the magnetic flux, ϕ, embraced by the coil, C, is at once a function of i and v_p. We have $\phi = f(i, v_p)$, whence two new parameters for the control circuit: $\frac{\partial \phi}{\partial i}$, $\frac{\partial \phi}{\partial v_p}$.

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Let us designate the four parameters of the magnetron by symbols which recall their dimensions, as follows :—

$\frac{\partial i_p}{\partial v_p} = \frac{1}{r_p}$ (Conductance). $\frac{\partial \phi}{\partial i} = l$ (Self-induction).

$\frac{\partial i_p}{\partial i} = k$ (Numerical coefficient). $\frac{\partial \phi}{\partial v_p} = t$ (Time).

Let us consider the actual values of these parameters for values, v_{p_0}, i_{p_0}, ϕ_0, i_0, in the neighbourhood of which the device is supposed to work, and let us imagine that we superimpose on the continuous current, i_0, by means of the transformer, T_i, a weak current $j \sin \omega t$ to be amplified. To determine the amplified alternating electromotive forces and currents, $V \sin \omega t$, $J \sin \omega t$, and the alternating flux, $\psi \sin \omega t$, embraced by the coil, C, we shall have, when supposing that the anode circuit includes, through a transformer, T_0, of ratio 1, an external resistance R, the following equations :—

$$\begin{cases} J = \frac{V}{r_p} + kj \\ \psi = lj + tV \\ V + JR = 0. \end{cases}$$

These equations correspond to :—

$$\begin{cases} J = \frac{kr_p}{r_p + R} j \\ V = -\frac{kr_p R}{r_p + R} j \\ \psi = \left(l - \frac{tkr_p R}{r_p + R}\right) j. \end{cases}$$

Knowing $\psi \sin \omega t$ and the resistance r, of the coil, C, it is easy to compute the potential difference at the terminals of the coil, C, and to calculate all the deducible matter concerning amplification and generation.

MARIUS LATOUR.

Paris,
October 4th, 1921.

TRIODE CHARACTERISTICS WITH HIGH GRID POTENTIAL.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—The explanation given by Mr. Appleton in the September RADIO REVIEW of a certain type of grid current curve is of very great interest but is open to criticism. Grid curves of this type (Fig. 1) appear only to occur when the space current is temperature limited and are always associated with an anode current of the form shown in Fig. 1. It has been found that provided the electron emission from the filament is ample both grid and anode current curves are of the form shown in Fig. 2, neither showing any abnormality at the point where $V_a = V_g$.

It is difficult to see why in the first case there should be a considerable emission of electrons having high initial velocities and in the second case apparently no secondary emission.

It is possible, however, to account for this type of grid curve without postulating secondary emission. Since when it occurs the space current is temperature limited it can be assumed that the electrostatic field of the valve is not greatly affected by the space charge.

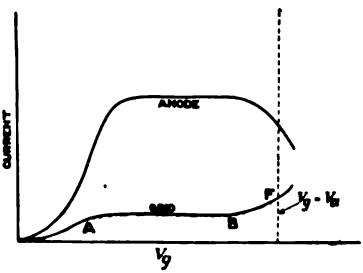

FIG. 1.

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It can be shown from the ordinary electrostatic theory of the cylindrical valve that the expression for the charge per unit length of the grid contains a factor

$$\left(V_g - V_a \cdot \frac{\log \frac{d'}{d_f}}{\log \frac{d_a}{d_f}} \right)$$

where d_a = anode diameter.
d' = grid diameter.
d_f = filament diameter.

and is otherwise independent of V_a and V_g. In most cylindrical valves $\log \frac{d'}{d_f} \Big/ \log \frac{d_a}{d_f}$ is equal to 0·8 or 0·9.

It follows therefore that this point $V_g = 0{\cdot}8\ V_a$ is a transition point where the electrostatic field changes from the type of Fig. 3 to that of Fig. 4.

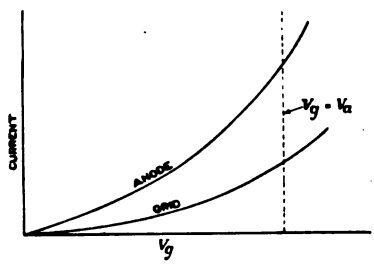

FIG. 2.

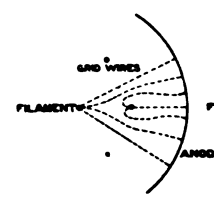

FIG. 3.

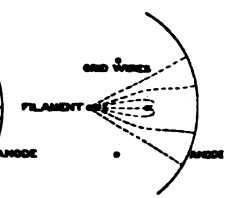

FIG. 4.

The charge on the grid is negative until $V_g = 0{\cdot}8\ V_a$ and therefore up to this value of V_g the grid is actually repelling electrons, the grid current being due to mechanical obstruction of electrons which have attained considerable radial velocities before approaching the neighbourhood of the grid wires. It will be found experimentally as might be expected that the fraction of the space current going to the grid is nearly equal to the fraction of the grid cylinder surface obscured by wires. Above the point $V_g = 0{\cdot}8\ V_a$ the grid is attracting electrons and the grid current naturally increases at the expense of the anode current.

It has been found experimentally that the point B when the grid current curve begins to rise steeply occurs approximately at $V_g = 0{\cdot}8\ V_a$ over the range of receiving valve anode voltages.

The question of secondary emission from the anode might of course be attacked experimentally by comparing the watts received by the anode with the product of the anode current and volts but the difficulties would probably be serious.

A. C. BARTLETT.

The Research Laboratories of the General Electric Co.,
London.
September 27th, 1921.

ERRATA.

Page 550, *Abstract No.* 2441, *the second reference should read: Radioélectricité*, 1, p. 147 D June, 1921.

Page 561 *Abstract No.* 2547, *title should read:* "The Effect of a Uniform Magnetic Field on the Motion of Electrons between Coaxial Cylinders."

Page 531, in the first line of equation (15) for $E^2\lambda$ read $F^2\lambda$.

Page 533, in the 6th and 7th lines of par. 9 the values of H should be $3{\cdot}7 \times 10^{-10}$ and $1{\cdot}1 \times 10^{-10}$ respectively.

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THE RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

VOL. II DECEMBER, 1921 NO. 12

Editor :
PROFESSOR G. W. O. HOWE, D.Sc., M.I.E.E.
Assistant Editor :
PHILIP R. COURSEY, B.Sc., F.Inst.P., A.M.I.E.E.

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Editor: Prof. G. W. O. HOWE, D.Sc., M.I.E.E. Asst. Editor: PHILIP R. COURSEY, B.Sc., A.M.I.E.E.

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INFORMATION FOR CONTRIBUTORS

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200 . . .	1 10 9	2 9 3	3 6 0	4 5 0	4 17 0	5 12 9	1 6 3
250 . . .	1 12 3	2 12 0	3 10 0	4 9 9	5 2 0	5 18 3	1 9 0

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THE
RADIO REVIEW

VOL. II DECEMBER, 1921 NO. 12

Editorial.

The Natural Frequency and Self-capacity of Coils.—At a paper on the calibration of wavemeters read before the Physical Society of London in 1912 we showed that the self-capacity of coils could be allowed for to a high degree of accuracy by assuming a condenser of constant capacity to be connected across the terminals of the coil. It appeared somewhat surprising that this effective self-capacity was independent of frequency right up to the natural frequency of the freely oscillating coil, but subsequent tests made by various experimenters, notably by Hubbard, have fully confirmed this result. This fact simplifies very considerably the allowance which has to be made for the self-capacity of the coil. In our address as Chairman of the Wireless Section of the Institution of Electrical Engineers we have shown that if it be assumed that the current is distributed along the coil according to a sine law then the self-capacity must necessarily be independent of the frequency and dependent only on the radius of the coil, to which it is directly proportional, and on the shape of the coil. The capacity will also depend on any dielectrics of specific inductive capacity greater than unity which may be near the coil, *e.g.*, the insulation on the wire and the bobbin if any on which the coil is wound. If the current has a sine distribution, the charge on the coil must necessarily have a cosine distribution and the current and charge will have a simple relationship depending on the frequency. For a coil of a given ratio of length to diameter the E.M.F. induced in the whole coil by such a distributed current can be calculated; it will depend of course on the frequency. The E.M.F. must be equal however to the electrostatic P.D. between the ends of the coil due to the distributed charge, which can also be calculated. Now there is only one frequency at which the E.M.F. can be equal to the P.D. and that frequency which one thus obtains is the natural frequency of the coil. Strictly speaking, the current and charge must have such a distribution along the coil that the E.M.F. and P.D. neutralise each other over every section of the coil and not merely at the terminals and this is the criterion of the correctness of the assumed distribution. On the assumption of a sine distribution a formula can be established for the capacity which connected across the coil gives the effect of the self-capacity, and this formula is independent of the frequency employed. Another fact which is of interest is that the calculated effective self-capacity varies very little with the length of the coil, if the diameter is kept constant, which agrees with the result of experiment.

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The High-frequency Resistance of Coils.—Papers of a theoretical character read before the Royal Society are apt to be overlooked by those engaged in the design and construction of apparatus; we therefore wish to draw special attention to a paper read in June by Mr. S. Butterworth, of the National Physical Laboratory, on the high-frequency resistance of coils. After a somewhat complex mathematical analysis of the losses occurring in a cylindrical wire situated in an alternating magnetic field the results are applied to the losses in coils and very important practical results are obtained which are compared with measured values. Although some discrepancies of an interesting nature are found to exist between the calculated and the measured values, these detract little from the value of the results. Formulæ are given to enable one to choose the best shape and size of coil and the best stranding to employ to fulfil given conditions. Perhaps the most striking fact brought out in the paper is the excessive losses in the end turns of short coils. If the coil be divided into four equal sections, then of the total eddy current losses in the coil 93 per cent. take place in the two end sections and only 7 per cent. in the two middle sections. Tests made at the Imperial College by Mr. A. G. Warren on the initial rise of temperature of the various turns on first switching on the current gave similar results. It shows that great care is necessary in deducing high-frequency resistance from single thermojunction measurements on coils since the temperature distribution with A.C. is likely to differ considerably from that with D.C. A point of considerable academic interest is that the two inner sections of the coil have the higher effective resistance, since they act as the primary of a transformer of which the two outer sections constitute the secondary and the excessive losses in the latter cause an excessive effective resistance in the former. Mr. Butterworth shows that the end turns may even have a negative effective resistance in spite of the large losses occurring in them.

The Transmission of Wireless Signals between Toulon and Tahiti.*

By Lieutenant M. GUIERRE.

Objects.

The objects of the radiotelegraphic investigations carried out by the s.s. *Aldebaran* were to receive and measure the strength of the special signals sent out by the radio stations at Lyons-la Doua (French Army), and Nantes-Basse Landes (French Navy).

The research was particularly concerned with :—

(1) The reception of radio signals in the Indian Ocean, with a view to establishing the laws of wave propagation over an almost completely continental path ;

* Abstracted from the *Bulletin de la Société Francaise des Électriciens*. See RADIO REVIEW Abstract No. 2774 in this issue, for references.

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(2) Reception at ranges of 7,000 to 10,000 km;
(3) Comparison of day and night ranges;
(4) Reception in the neighbourhood of Noumea and the Antipodes;
(5) Investigation of the field strength at Tahiti (the waves travelling almost completely over sea).

Route.

The route followed by the sloop *Aldebaran* during the six months' voyage was as follows: Toulon, Port-Said, Djibouti, Mahé-des-Seychelles, Diego-Suarez, Saint Denis (Reunion), Mahé-des-Seychelles, Colombo, Singapore, Bataira, Freemantle (West Australia), Melbourne, Auckland, Antipodes, Bluff Harbour (New Zealand, South Island), Auckland, Noumea, Loyalty Islands, Fiji Islands, Samoan Islands, Tahiti.

Aerials and Wavelengths.

The wavelengths used for the investigations were 9,000 and 11,000 metres for the transmissions from Nantes, and 15,100 metres for Lyons. The aerials of these stations had the following characteristics:—

Lyons.—Inverted **L** antenna, with the horizontal portion in east-west direction, consisting of twenty copper wires 840 metres (2,750 feet) long, supported by eight towers 180 metres (590 feet 6 inches high). Width of aerial = 160 metres (525 feet). This antenna had the following constants: Static capacity, at 6,050 metres wavelength, $= 3{\cdot}9 \times 10^{-3}\ \mu F$; and at a wavelength of 15,600 metres,

$$R = 2{\cdot}1\ \Omega,\ C = 3{\cdot}7 \times 10^{-3}\ \mu F,\ L = 1{,}875\ \text{mH}.$$

Nantes.—**T** antenna, having a horizontal part composed of ten wires with fan-shaped down leads in the centre; height above the ground 180 metres (590 feet 6 inches); six towers; length of horizontal part, 500 metres (1,640 feet), width, 200 metres (656 feet); capacity of the aerial $18 \times 10^{-3}\ \mu F$, inductance 125,000 cm. Series inductance for

$\lambda = 9{,}100$ m, 1,100,000 cm.
$\lambda = 11{,}000$ m, 1,700,000 cm.

Effective resistance of the antenna for

$\lambda = 9{,}000$ m, 3 ohms.
$\lambda = 11{,}000$ m, 3·6 ohms.

Aldebaran.—Aerial consisted of two 6-wire cages 0·93 m (3 feet) diameter parallel with the deck. Total length of antenna = 37 m (121 feet 4 inches), height above deck = 23 m (75 feet); down leads formed by two small cages in **V** shape.

Signals and Hours of Transmission.

Continuous wave transmission by arc generators was employed. The aerial current at Nantes was 200 amperes, and at Lyons 185 amperes. The signals were sent out from Nantes at 0823 h, and 2023 h, G.M.T., on 9,000 metres, at 1023 h and 2053 h on 11,000 metres wavelength, and from Lyons at 0845 h G.M.T.

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Previous Work.

It may be of interest to recall that M. H. Poincaré was the first to investigate the law of the decrease of the amplitude of the oscillations. This law as given by him was of the form $\epsilon^{-md/\sqrt[3]{\lambda}}$, d being the great-circle distance from the transmitter, λ the wavelength, and m an appropriate factor. As a result of the investigations of March, corrected by von Rybczinski, this law takes the form of a product of two terms, one being $2/A\sqrt{\theta \sin \theta}$, and the other Poincaré's exponential, θ being the angle which the two stations subtend at the centre of the earth.

The only practical verification of these theoretical results was made by Austin over ranges up to 3,700 km over sea, who derived the formula.

$$I_R = 4{\cdot}25\, I_S \frac{h_r h_s}{\lambda D} \epsilon^{-0{\cdot}0015D/\sqrt{\lambda}}$$

This formula is the only one now used in the design of radio stations, but the measurements made by the *Aldebaran* show that it is inaccurate for long ranges.

Method of Measurement.

The possibility of effecting reliable measurements of signal strength on board ship is due to an application of a method due to M. de Bellescize.

(1) *Object of the Method.*—To investigate the variation of the electromagnetic field set up by a station transmitting with constant power and wavelength, as a function of the distance. In all the measurements carried out on board, the inductive effect of the field under investigation on an open aerial was compared with the induction from a local transmitter under the control of the receiving operator. All measurements are relative, and are referred to an arbitrary but invariable scale.

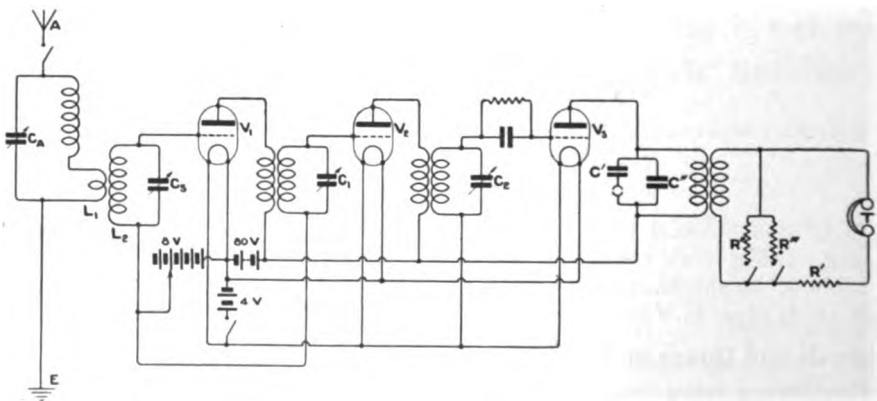

FIG. 1.—Receiving Circuits.

(2) *Arrangement of Apparatus.*—The receiver (Fig. 1) consisted essentially of an inductive coupling L_1L_2 between the receiving aerial A and the two-

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stage amplifier V_1V_2. The detecting valve V_3 is interposed between this amplifier and the receiving telephones T. The coupling between L_1 and L_2 can be varied over wide limits by sliding the primary along a graduated scale. The telephones T are shunted by a variable resistance (R″ or R‴) with a resistance R′ of 2,500 ohms placed in series; and the circuit is suitably earthed in order to keep the static potential constant and to eliminate currents in the telephone receivers due to their capacity to the operator and earth—such currents interfere with the measurements made with small values of shunts R″, R‴. The transformer primary is shunted by a capacity C′ + C″, the condenser C′ being put in or out of circuit by means of a plug; on removing the plug, the sensitiveness of the amplifier is increased, but so also is the tendency to oscillate. A heterodyne not shown in the figure completes the arrangement for the reception of undamped waves.

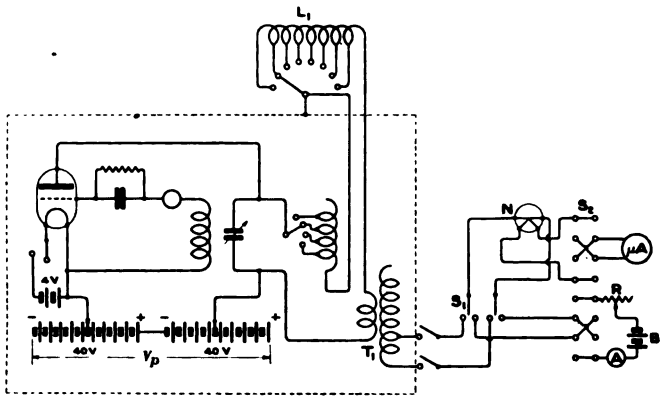

FIG. 2.—Arrangement of Auxiliary Transmitter.

The auxiliary transmitter (Fig. 2) employs an oscillating valve and is suitably screened, with the exception of the coil L_1 which comprises the radiating part of the transmitter. The number of turns n in this coil is adjustable between 1 and 8.

The screen is connected to a point on the coil by a short wire of very low resistance; the radiation from the coil may be stopped by a short circuiting switch. Calling the effective oscillating current in the auxiliary transmitter i_a its inductive effect Z is represented, for constant wavelength, by the product ni_a. The current i_a may be adjusted by varying the plate voltage V_p, between the limits 8 and 80 volts. The distance between the coil L_1 and the antenna is so adjusted that with the receiver at its maximum sensitiveness, and the product ni_a at its minimum value, the radiation from the auxiliary transmitter can just be heard.

Each measurement consists in the adjustment of the two transmitters under comparison (namely, the signals from the station under investigation and those from the auxiliary transmitter) so as to produce the same effect

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on the telephone. The sensitiveness of the receiver should of course remain constant throughout the test. Consequently the following ought to be practically constant during the measurements :—

Inductive coupling between aerial and secondary circuit.
Tuning of circuits.
Impedance of the plate circuit of last valve.
Sensitiveness of the detector.

These last conditions may be attained as follows. The shunts R″ and R‴ should be of the same value, and small compared with the series resistance R′; the coupling between the heterodyne and the receiver should be sufficiently close so that the rectifying effect of the detecting valve is linear.

When, however, the impedance of the shunts R″ or R‴ is small compared with that of the telephone T, the strength of the signal due to the auxiliary station will remain constant if it is equal to the product of **Z** and the telephone shunt ; this provides a means for testing proper adjustment of the apparatus.

During a reading, the station to be tested and the auxiliary station transmit alternately continuous dashes of ten seconds duration on exactly identical wavelengths. The operator makes the following adjustments to equalise the signal strengths :—

Adjustment of the auxiliary inductive effect **Z** which is proportional to ni_a; adjustment of shunts R″ and R‴ so that the shunt R″ used with the field **Z** gives the same strength as when the shunt R‴ is used with the test signals. The strength of the latter is then $ni_a \frac{R''}{R'''}$. This is reduced if necessary to refer to a constant current of 200 amps in the transmitting aerial.

(3) *Investigation of the Inductive Field* **Z** *and of the effect of the Telephone Shunts.*—(*a*) Measurement of the oscillatory current i_a in the auxiliary transmitter.

This measurement is effected by means of a continuous current micro-ammeter μA (0—150 micro-amps) connected through a transformer T_1 and the thermo-element N (Fig. 2).

Two switches S_1 and S_2 enable the standardisation of arrangement to be effected by means of continuous current from the battery B. This current may be adjusted by a resistance R and is read on a milliammeter A. In order to determine the current i_a as a function of the plate voltage V_p the following operations must be carried out :—

(1) Standardisation of the thermojunction by continuous currents. For this purpose the switch S_1 is thrown over to connect in the battery B and the resistance R is adjusted to a convenient value. The continuous current i is read on a milliammeter and the two successive deflections δ_1 and δ_2 of the microammeter are read for the two positions of the switch S_2. The continuous current i_c given by the thermoammeter under the influence of an alternating current i_a assumed equal to i, will therefore be $i_c = \frac{\delta_2 - \delta_1}{2}$. The curve of

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$i_a = \phi(i_c)$ can then be plotted between the possible limits of observation—that is $\delta_2 < 150\ \mu$A. Normally i_c is approximately proportional to i_a^2.

(2) Standardisation of the current i_a as a function of the plate voltage V_p. For these measurements the switch S_1 is thrown over to connect in the transformer T_1. The voltage V_p is read on a voltmeter and the current i_a is determined from the reading i_c of the microammeter by means of the curve which has already been plotted. Prolonged tests have shown that with a constant filament temperature and between the limits of 8 and 80 volts with a given value, the alternating current is stable and is approximately proportional to V_p.

(*b*) Relation between the telephone shunt and the local current i_a for constant sound in the telephone.

The induction from the local transmitter is evidently proportional to the oscillating current producing it. This means that if the receiver is properly adjusted (see § 2) the telephone shunt R'' (or R''') ought to be inversely

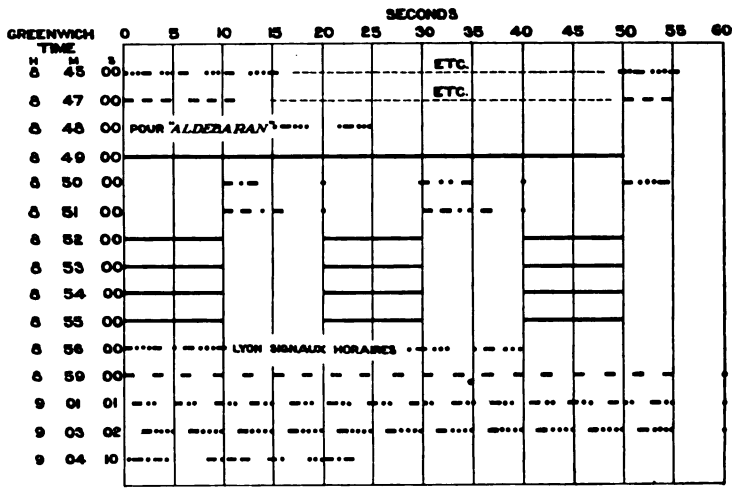

FIG. 3.

proportional to i_a for constant sound in the telephone. The experimental verification of this statement is difficult since each variation of the plate voltage introduces a considerable change in the transmitted wavelength, and consequently also in the received heterodyned beat note. This difficulty is overcome by retuning the transmitter for each value of V_p and of i_a so as to produce the loudest sounds in the receiver which is maintained at a constant adjustment. Complete silence is necessary for successful results and each measurement is obtained as a result of a large number of readings.

(*c*) Effect of number of turns n.

Assuming that the potential of the coil J is maintained constant by an

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earth connection the inductive effect is proportional to n. Hence if the receiver is properly adjusted (see § 2) the telephone shunt R'' (or R''') should be inversely proportional to n for a constant sound in the telephones. This may be checked for any two values of n such as n_1 and n_2 by finding the appropriate shunts R'' and R''', for constant sound. The adjustments of the coil J and of the telephone shunt should be effected simultaneously as the accuracy of the measurements depends largely on the continuity of the impressions received by the operator. These measurements which may be easily and quickly carried out should be repeated from time to time as a check on the proper adjustment of the apparatus.

Tests (*b*) and (*c*) above were carried out before the departure of the *Aldebaran* for shunts between 5 and 150 ohms, as it was thought unwise to use values outside these limits.

(4) *Tests* (*Basse Landes and Lyons*).—The station under investigation made the following transmissions (Fig. 3) :—

(*a*) Starting period during which rough adjustments of the receiver were made.

(*b*) A series of V's for fifty seconds used first for adjustment of the heterodyne and afterwards for the exact adjustment of four condensers C_A, C_S, C_1, C_2 (Fig. 1). The strength of the spacing wave was always adjusted to be less than that to be received from the local transmitter. For this purpose, at small and medium distances (probably up to 3,000 km) the local radiation was adjusted to its maximum value and the heterodyne tuned to give complete extinction of the spacing wave. The note thus obtained for the marking wave is lower than that corresponding to maximum sensitiveness of the receiver, but as the signals are very strong under these conditions no difficulty was experienced. At greater distances when the receiver signals became so weak that the auxiliary transmission and the signals could be equalised it became imperative to tune the heterodyne so as to obtain the strongest signals.

(*c*) A series of six dots each preceded by a distinctive signal for use in connection with the chronographs controlling the alternation of the dashes.

(*d*) The last four minutes were utilised for an uninterrupted series of ten-second dashes sent alternately by the station under investigation and by the local transmitter. During the first dashes the note of the auxiliary station was adjusted to equality with that of the incoming signals. The following dashes were used for equalising the strength by variation of the induction from the local transmitter and if necessary of the comparison shunts R'' and R'''. In order to avoid the variations of note which would be caused by switching on and off the filament current of the valve at the auxiliary transmitter the coil J was short circuited when it was required to stop the local radiation.

Value of the Method.

The long experience obtained in the use of this method enables us to testify to its excellence in practical operation. All the necessary operations—adjustment of tuning—starting of chronographs—equalisation of pitch and

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strength of sound—soon became habitual. A measurement by equalisation of two sounds is much more accurate than a measurement made by extinction of sound, since in the latter case serious errors are often made. The continued tests have shown that in the first case the personal error due to the observer should not exceed 15 per cent. The essential feature of this method is to ensure constant reliability of results in spite of variations in the sensitiveness of the ear. This renders it possible to change the operator.

Criticism of Results.

(A) ROUTE TOULON–REUNION–MELBOURNE.

During this voyage investigation was made of wave propagation over an almost entirely overland route: firstly Toulon–Reunion (9,350 km), then Toulon–Melbourne (17,200 km). The curves of the results give the type of variation of the strength of reception in terms of distance. Their examination shows:

(1) That the range at night was always greater than during the daytime; at the end of the journey Toulon–Reunion we were at the limit of daylight reception but the night signals were very easily readable in spite of storms. At the end of the Toulon–Melbourne test daytime reception was zero, night time reception very strong, and moreover each of these routes was at the time of transmission either entirely in daylight or entirely in darkness.

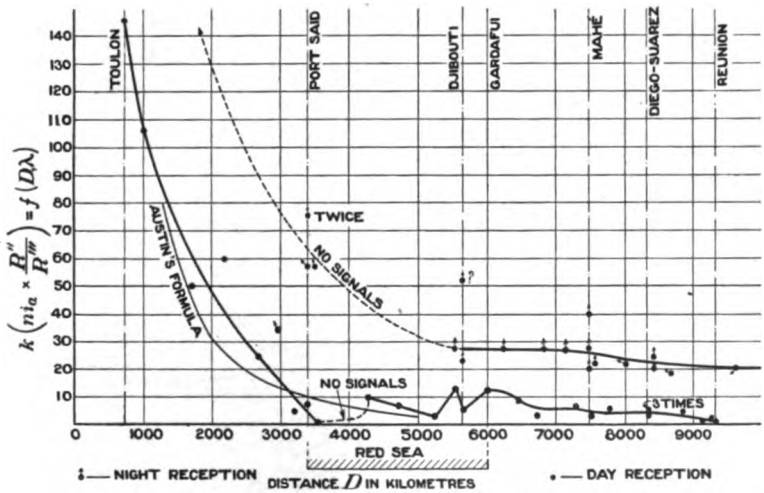

FIG. 4.—Curves of Received Signal Strengths between Toulon and Reunion. Transmission from Nantes on 9,000 m.

(2) That the variations in reception were greater by night than by day;
(3) That the signal strengths were in the order of the wavelengths—15,000, 11,000 and 9,000 metres;

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(4) That the crossing of the Red Sea was accompanied by irregularities in the reception of 9,000 metre signals which were not experienced on 11,000 metres.

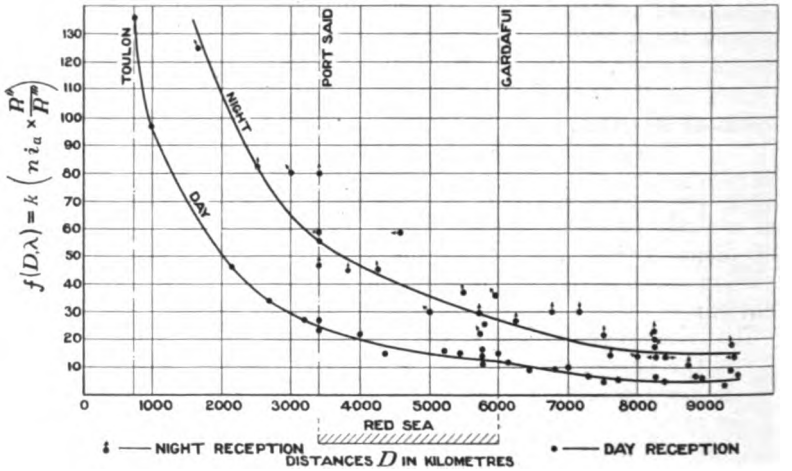

Fig. 5.—Received Signal Strengths between Toulon and Reunion. Transmission from Nantes on 11,000 m.

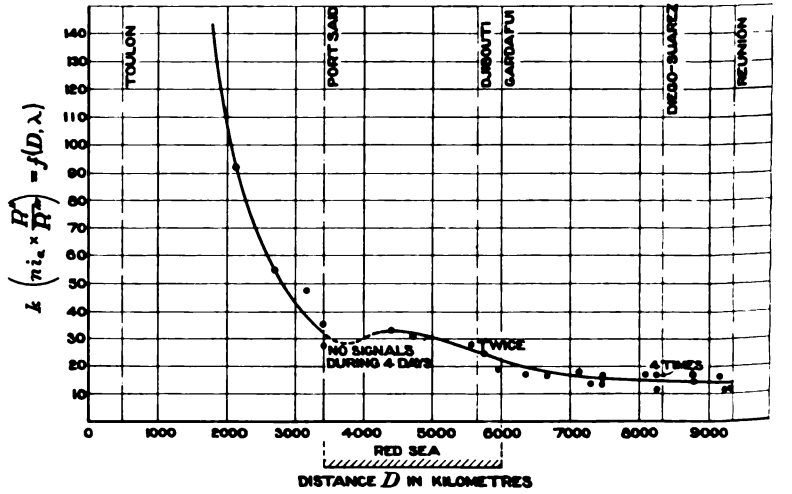

Fig. 6.—Received Signal Strengths between Toulon and Reunion. Transmission from Lyons on 15,000 m.

Alternative Graphical Representation of the Results.—The factor $f(D,\lambda)$ which is proportional to the received signal strength and which is plotted as ordinates of the preceding curves (Figs. 4—6) has the form

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$$f(D,\lambda) = k\frac{\epsilon^{\frac{\alpha D}{\lambda}}}{D},$$

the numerator of this fraction being the absorption coefficient. If we plot as ordinates for the curves not this function $f(D,\lambda)$ but its product by the distance D, we shall show up the variations in the absorption. On plotting these figures we obtain a series of points the separation of which indicates

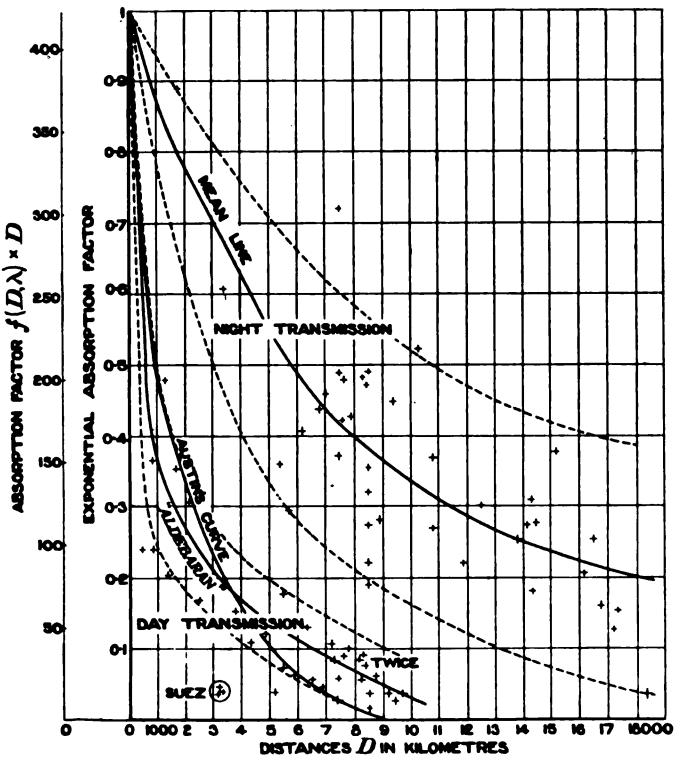

FIG. 7.—Curves for Transmissions from Nantes on 9,000 m. Absorption factors (reduced to 1,000 km) as functions of the distance.

the constancy of the transmission—a stability which can be defined by the ratio of the separation of the envelope curves of these points to the mean ordinate of those curves at any given value of D. The determination of the wavelength to be employed for communication over a given distance depends in fact on the relative and absolute values of these two factors. This method of plotting which was designed by M. de Bellescize has also the advantage of enabling a better determination to be made of the curves near their origin, since evidently at zero distance the exponential factor becomes unity, and our curves for night and day transmission should cut the axis of ordinates at this point.

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Austin's Curves.—Points calculated by Austin's formula can be plotted out in a similar manner. From an examination of these curves, it is evident, apart from the above considerations :—

(1) That the absorption is less and at small distances varies less between night and day, and that at the limit of observations, the advantages of night transmission increase with the distance;

(2) That the constancy of transmission defined above is greater by night than by day;

(3) That Austin's formula gives inadequate results for ranges in excess of 4,000 km, and increasingly so the greater the wavelength;

(4) That, since at distances where it is no longer possible to count on reception, the signals still exist, although they are very feeble, the progress to be made lies rather in the direction of utilising this residual energy than in further increasing the power of the transmitting stations.

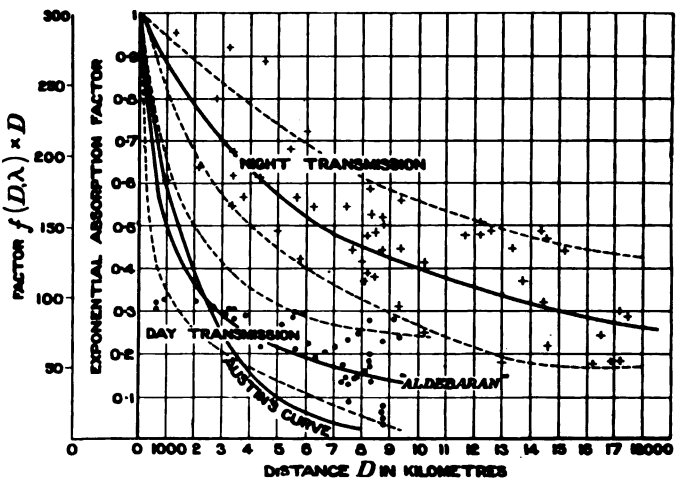

FIG. 8.—Curves for Transmissions from Nantes on 11,000 m, giving absorption factors (reduced to 1,000 km) as functions of the distance.

Experimental Results.—It does not appear that the atmospherics are uniformly stronger in tropical or equatorial regions that we have passed through than they are in our own latitudes, it is more a question of seasons and places, and in any case they were always stronger on a wavelength of 15,000 m than on those of 11,000 and 9,000 m.

On October 2nd, at Diego-Suarez (8,400 km) at 0823 G.M.T., Nantes was heard signalling to **FRI**, in spite of a slight storm. At St. Denis, Reunion (9,450 km), at 0823 G.M.T., Nantes was heard transmitting to **FRI.** These signals were readable except during storm maxima, and were verified by the log of the station. At these places the limit of daytime reception was reached and no regular service was possible using a ship's antenna, but the night reception of Nantes remained very strong. The log of signals

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received shows that on October 8th at 2023 G.M.T. at a distance of 9,450 km, very readable signals were received with the coupling loosened by 10 cm, in spite of a violent storm.

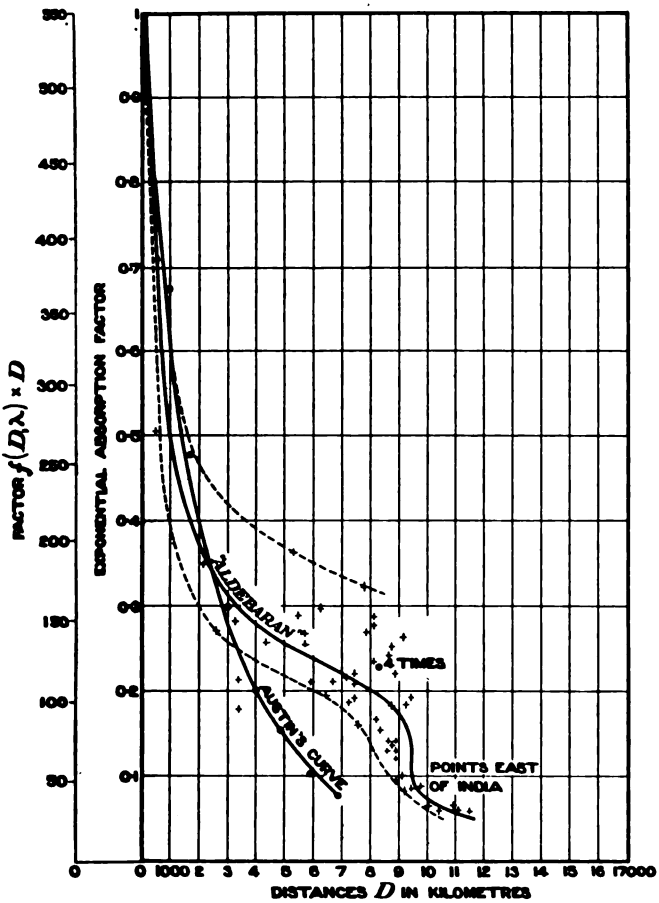

FIG. 9.—Curves for Transmissions from Lyons on 15,100 m, giving absorption factors (reduced to 1,000 km) as functions of the distance.

The reception of Lyons was excellent by day as well as by night, and at Reunion as at Diego-Suarez, communications were frequently received from this station by day or night. The messages from Lyons were read very easily at Melbourne (17,200 km) when they were sent at night.

(B) INVESTIGATION OF PHENOMENA AT THE ANTIPODES.

The belief in an increase of potential at the antipodes has up to the present been based on formulæ, and on the particularly strong reception

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observed in New Zealand, and information furnished by the officers of that country indicate a much stronger reception in the south (at Awarua) than in the north (Awanui). According to Mr. Davis who has been in charge of the station at Awarua for a long time the Eiffel Tower has been heard by that station since 1917 between 6.30 and 7.30 a.m. local time, much stronger than any other European station—two to three times stronger even than Nauen. On the other hand the station at Awanui is reputed to have only mediocre reception.

The route adopted by our cruise of investigation was: Auckland, Chatham Is. (wireless station at 100 miles from the antipodes of Lyons), antipodes of Lyons; antipodes of Nantes; Bluff Harbour (a port near the Awarua radio station), Auckland.

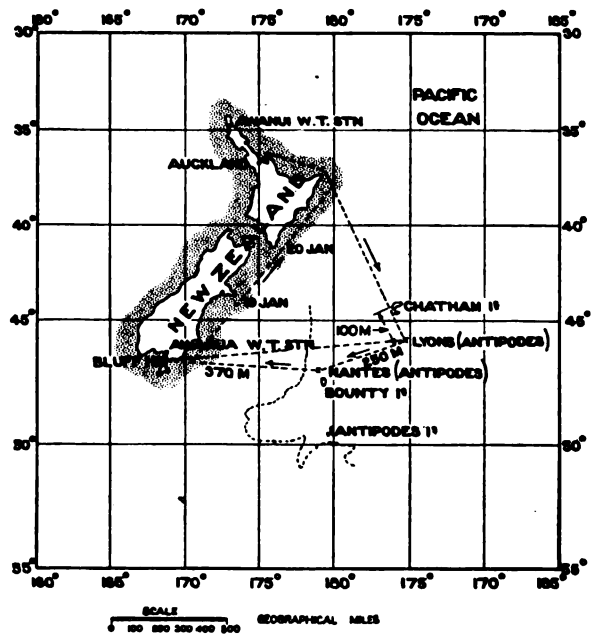

FIG. 10.—Chart showing Route followed in investigating the Phenomena at the Antipodes of the Transmitting Station.

All the figures which follow correspond to transmissions made with uniform intensity of 200 A for Nantes and 185 A for Lyons. It should be noticed that on January 2nd at Auckland the Nantes daily signals (on 9,000 metres) which had been lost after leaving Colombo, were again received; the daytime and night time signals were of very nearly identical strengths. This is easily explained, because transmissions made to the antipodes day and night at twelve-hour intervals arrive by practically the same paths (half the great circle is in darkness), one from the east and the other from the west.

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The operators in the Chatham Islands state that during 1918 they often heard Lyons about two o'clock mid-day, on their T aerial 100 metres long and 45 metres high, using a valve detector without amplification.

However, at 100 miles to the north-west of the antipodes of Lyons, the *Aldebaran* only heard that station very faintly—coefficient 2·8.

On January 8th, at 0845 at the exact antipodes, in spite of rain which diminishes reception, Lyons was received with coefficient 11·5, and the message was taken down to the last letter. This strengthening only gradually diminished with increased distance to the south-west, and at Bluff Harbour, 570 miles from the antipodes, the coefficient was still 3·3, whereas it was 2·8 at 100 miles in the north-west of the antipodes.

The reception of Nantes on 9,000 metres gave rise to somewhat different phenomena.

At 120 miles to the north-west of the antipodes reception was no better than at Auckland ; at 25 miles it was 2·4.

On January 10th, at the exact antipodes, the Nantes signal at 0823 was received with strength 13·3 with very sharp tuning. But on the 11th at the same place and time this strengthening had disappeared, and the received strength was 1·9 ; in the west it diminished also, then increased at Bluff Harbour where it reached 2·8.

The bad working of Nantes on 11,000 metres prevented experiments on this wavelength.

The two wavelengths 15,000 m and 9,000 m seem to act differently, the first causing a strengthening at the antipodes, then a progressive falling off to the west, the second showing a strengthening at the antipodes and at Bluff with very weak reception between the two.

Strengthening of Nantes.—At the wireless station of Awarua (South Island) the aerial is of the Telefunken umbrella type, with one mast 140 metres high, twenty-four wires 50 metres long, having a fundamental wavelength of 1,390 metres. A single valve receiver without amplifier was used. Three consecutive nights spent at this station enable me to state that this station can easily receive the European stations ; in the evening Nantes, Lyons, Nauen and the Eiffel Tower could be heard with intensity proportional to the power of the stations sending ; but in the morning the Nantes signals on 9,000 metres could always be heard much better than any of the other signals, especially than the one from Lyons sent almost immediately afterwards.

The table of receptions drawn up by Mr. Willis, who is in charge of the station, emphasises this fact ; it is reproduced below.

The measurements made on board at the same time confirm these statements.

On leaving Bluff Harbour for Auckland, it was noticed that received strength decreased rapidly, although just at the head of Cook Straits one is nearer the antipodes than one is in the roadstead of Bluff Harbour.

Conclusions.—The phenomenon of the antipodes extends over a very restricted area (at least in the part explored) ; it is an interference phenomenon ; the position of nodes and anti-nodes ought to be constant while

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RECEPTION IN NEW ZEALAND.

To LIEUT. GUIERRE,
Aldebaran,
Auckland.

RADIO AWARUA,
20th January, 1920.

The following is a copy of the signals received during the visit of the French Wireless Mission to this station.

Date. 1921.	Time.	Wave-length.	Calls and Remarks.	Signal Strength.	Atmospheric Strength.
Jan. 15th	7.45 p.m.	9,000	**UA** sent routine	6	6
	8.15 p.m.	15,100	**YN** heard but X's too heavy.	4	6
	4.40 p.m.	11,000	**UA** unheard (missed through commercial work)	—	7
„ 16th	4.40 a.m.	12,600	**NNF** de **POZ** here note	7	6
	6.1 a.m.	4,000	**PSO** de **FL** note	6	6
	6.33 a.m.	15,100	**NFF** de **YN** messages	5	6
	7.56 a.m.	9,000	**UA** sent routine and note for mission	9	6
	8.21 a.m.	15,100	**CQ** de **YN** French Press	5	6
	7.54 a.m.	9,000	**UA** sent routine	5	5
	8.30 p.m.	15,100	**NFF** de **YN** note for **NSS**	4	5
	8.5 p.m.	12,000	**POZ** sending	4	6
	8.17 p.m.	15,100	**YN** sent routine.	5	7
„ 17th	4.30 a.m.	15,100	**YN** sent Press	5	7
	4.30 a.m.	12,000	**POZ** sending	7	
	6.50 a.m.	4,000	**IDO** and **FL** working	7	6
	6.50 a.m.	12,000	**POZ** working **NFF**	7	6
	7.54 a.m.	9,000	**UA** sent routine. Very strong while tuning but was weaker for routine	9/8	5
	8.30 a.m.	11,000	No sign of **UA**	—	6
	7.53 a.m.	9,000	**UA** sent routine.	4	6
	8.15 p.m.	15,100	**YN** sent routine but unreadable	3	7
	9.57 p.m.	11,000	No sign of **UA**	—	9
„ 18th	5.30 a.m.	12,000	**POZ** working	7	8
	6.15 a.m.	9,000	**IDO** de **FL** messages	6	6
	7.31 a.m.	9,000	**IDO** and **FL** still working	6	6
	7.33 a.m.	9,000	**OSN** de **FL** remarks	6	6
	7.35 a.m.	9,000	**IDO** de **FL**. Continues working	6	6
	7.50 a.m.	9,000	**UA** tuned but did not send routine	5	5

Signals are computed on the scale 1 to 9.

Yours faithfully,
A. L. M. WILLIS.

the wave remains the same, but the signal strength evidently depends on atmospheric conditions and on the distribution of land masses on the different routes. It is an unstable phenomenon, since what I observed for Nantes alone at Awarua has been observed at other times for the Eiffel Tower—and also at the Chatham Islands for Lyons.

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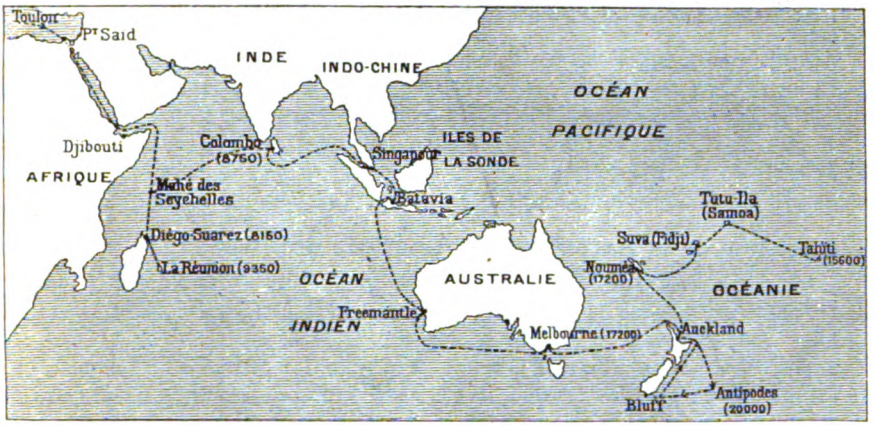

FIG. 11.—Route followed by the *Aldebaran*. The figures marked give the distances in kilometres from Nantes.

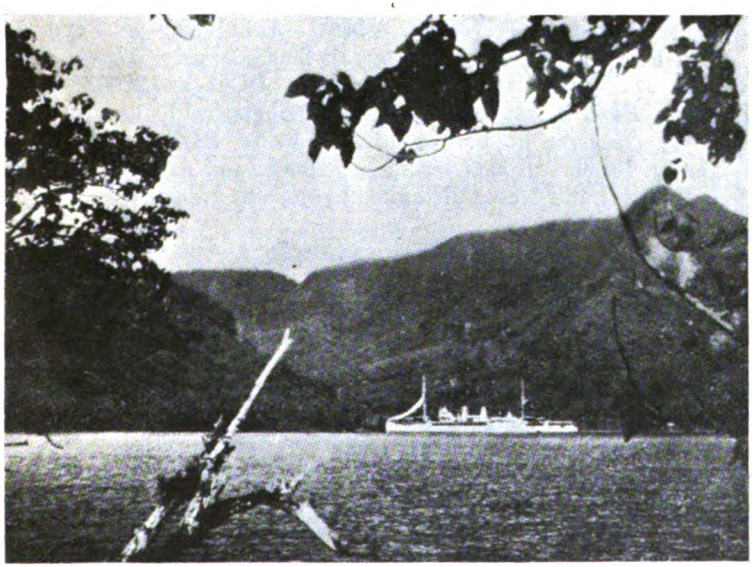

FIG. 12.—The s.s. *Aldebaran* at Papetoaï

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A detailed investigation of this phenomenon ought to be of great scientific interest.

Measurements taken at the same time on land and on board ship enable us to state that the minimum reception on board corresponds to a readable reception on a commercial station of average size. We may conclude that a station like Lyons, which we heard right up to the antipodes (without being able to read it between Melbourne and Auckland) should be able to maintain a service by day and night with all the places on our route.

Reception of other European and American Stations.

Between the Antipodes of Nantes and Bluff Harbour.—**NPM, NPN** strong, and **POZ** very strong at 1600h.; good at 2137h., G.M.T.; **NSS** good at 1400h. Lyons strong at 1845h. and 2100h. G.M.T.

At Bluff Harbour.—Heard **POZ** very strong (value of shunt for silence = 8) at 1700h.; **NSS** good at 1200h.; **NFF** very strong at 1200h.; **POZ** good at 1345h. (all G.M.T.).

Between Bluff Harbour and Auckland.—**NPM** very strong at 0145h.; **NSS** good at 1000h.; **NFF** good at 1050h.; **POZ** good at 1445h.; Lyons very strong (value of shunt for silence = 5) at 1530h., 1715h. and 2000h. At 2145h. heard **IDO** Rome calling **FL** feeble. At 2010h. heard **POZ** calling **NFF**—good transmission (value of shunt for silence = 20). **POZ** is often heard.

At 0610h. heard Rome feebly. **POZ** strong at 1230h., **IDO** readable at 1810h., **NSS** very strong at 1125h.

Between Auckland and Noumea.—**NSS** (Annapolis) good at 1400h., feeble at 0700h. Lyons (**YN**) strong at 2000h., fairly strong at 0300h. **PKI** strong at 2130h. Heard **PKI** calling **PCG** at 2200h. and **PKX** calling **AAP**. **POZ** is frequently heard, although feebly except at 2000h.

At Noumea (receiver in bad condition) heard **POZ** strong at 1500h., fairly good at 1800h. Lyons strong at 2000h. and fairly good at 0900h. Near New Zealand and New Caledonia, Lyons and Nauen were heard more than any other station.

Near Tahiti.—Heard only the American stations, even on those days when reception was very good.

Reception between Noumea and Tahiti.—From North Cape (North Island, New Zealand) we lost all contact with Nantes—Lyons could be heard but unreadable.

At Noumea we were obliged to add an amplifier to take down the Lyons message; that was 17,200 km from France—the same distance as Melbourne, where the night time sigs were very strong.

There is a difference of longitude of 1 h 30 m between these two points; and whereas in one case the whole of the route was in darkness, part of the other was in daylight; now in the preceding measurements, the sudden way in which we lost the night signals to the east of Melbourne, shows the tremendous influence of the position of the sun on transmission; to eliminate this factor it is necessary to change the time of transmission as the receiver moves.

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As the observer travels eastward the Nantes signals which travel towards him by the shorter of the two arcs of the great circle will have a route partly in daylight and partly in darkness. That is to say that at these distances they would not have been heard even had the atmospheric conditions been favourable. Now two cyclones having occurred within fifteen days, the humidity of the air caused two faults to appear—one in a coupling transformer which was soon repaired, the other in a telephone transformer, which we unsuccessfully attempted to rewind.

Reception between Noumea and Tahiti was therefore very weak, but at Tahiti itself a transformer lent by the local radio station was put in place and the sensitiveness of reception was re-established, since the standardisation transmitter could be heard with two turns and 16 volts. However, Lyons could not be heard at any time; Tahiti is 15,800 km from Paris and the local time is ten hours behind the French time, so that the 0845h. signals traversed a path which was two thirds in darkness; it is very surprising that even with the arrangement used at Noumea (amplifier Type 3^{ter}) we were never able to receive these signals at Tahiti.

Conclusions.

In spite of the limitations imposed by the bad condition of the receiving station, the fact that the standardisation transmitter could be heard with two turns, makes it seem probable that the signals are weaker in the Pacific than in the Indian Ocean. A report received from the *Aldebaran* on June 17th, has turned this probability into a certainty.

Moreover, why should the distribution of the waves be symmetrical round a sphere of such little homogeneity? Has not the phenomenon experienced at the antipodes given us a similar surprise? Not only should the law of attenuation of the energy over land and over sea be studied, but rather a world map of the distribution of the radiated energy. To this end regular transmissions could be arranged from a European high power wireless station which could be received by all ships, and their reports—like the meteorological reports—could be grouped together and thus furnish a quick solution of the problem.

Institution of Electrical Engineers Wireless Section.

At a meeting of the Section on November 9th, Dr. G. W. O. Howe delivered his address as Chairman of the Section.

After reviewing the highly successful work of the Section since its inception Dr. Howe took as the subject of his address the effective inductance and resistance to self-capacity of coils. He pointed out that the formulæ usually given for the inductance of portions of conductors could not be strictly so called and that the inductance of a portion of a circuit was difficult if not impossible to define. He described a new method of calculating the natural frequency of a coil and showed that the self-capacity was independent of the frequency if the current were assumed to have a sine distribution along the coil. This is dealt with more fully in the Editorial Notes, as is also a reference to some interesting results obtained by Mr. S. Butterworth in his work on the high-frequency resistance coils.

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Some Dutch Wireless Apparatus.

A description of the new Dutch marine type receiver manufactured by the Nederlandsche Radio Industrie was published in the July issue of the RADIO REVIEW. Details of other wireless apparatus of the same manufacture are illustrated and described in this article.

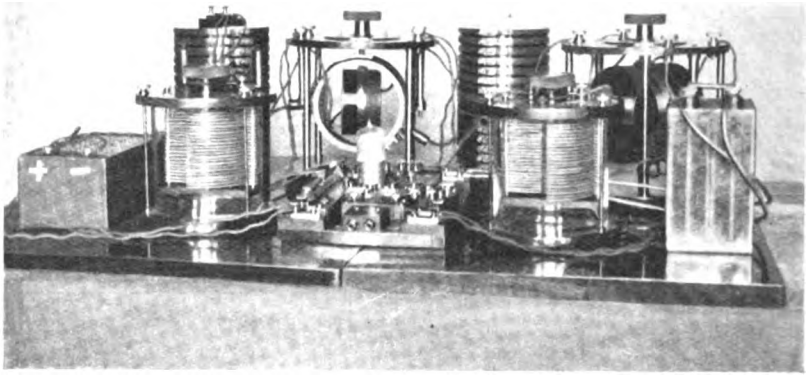

FIG. 1.—Receiver Type "T.K.A."

Combination Receiver Type "T.K.A."—This set shown in Fig. 1 is for use on wavelengths of from 400 to 20,000 metres and is specially constructed with universal plug contacts for experimenting on all kinds of diagrams. It can be used either as a simple combination, a short-wave receiver, a standard variable range receiver or it may be calibrated and used as a wavemeter.

A special feature of this set is the control panel, type C.S., of which there are two models "A" (Fig. 2) and "B," the "B" type panel having an extra in the form of a grid potentiometer. It is only necessary with the use of these panels to connect up three sets of terminals to put the receiver in action.

Other notable features of this set are the variable condensers, type "AM" of 0·00125 μF, coupling variometers, type "KV" model "H," inductances, type

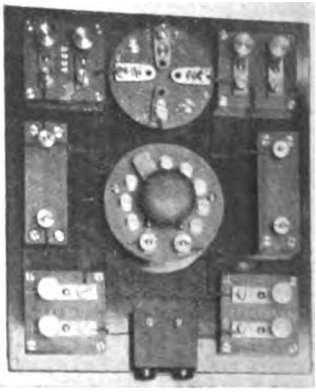

FIG. 2.—Type "A" Control Panel

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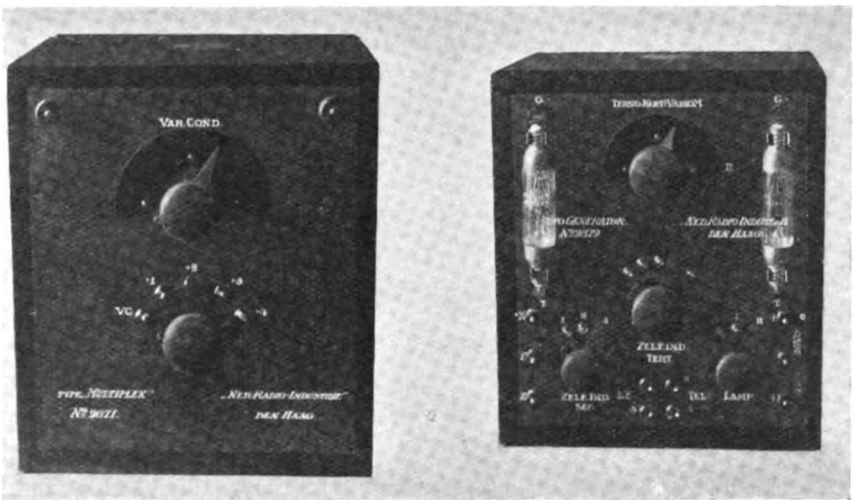

FIG. 3.—Parts of Loop Aerial Receiver.

"R 16," of the ring coil form, which latter the manufacturers claim hold advantages over honeycomb coils in that they have smaller self-capacity and high-frequency resistance, less liability to bad contacts, finer coupling if using variometers, only a portion of the circuit being coupled instead of the whole inductance and changing over is performed quicker and easier by their use.

Loop Aerial Receiver.—This consists of two sets (Fig. 3), a multiplex

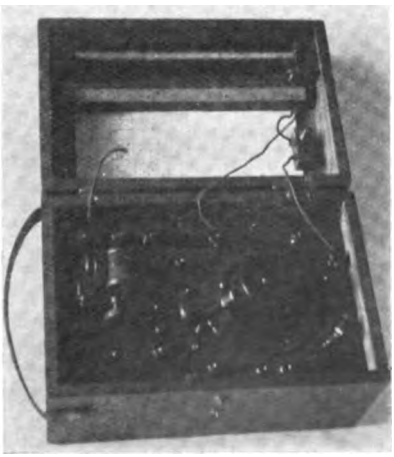

FIG. 4.—Decremeter Type "Delta."

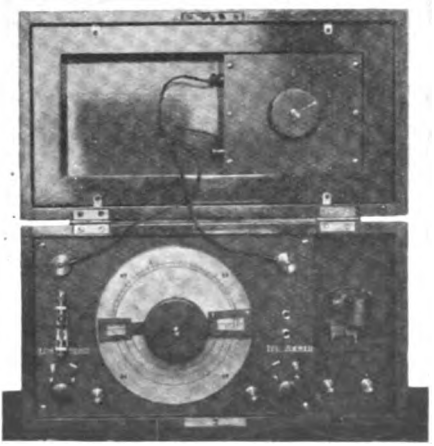

FIG. 5.—Standard Wavemeter.

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variable condenser and an autodyne generator. The condenser can be shunted in successive progression by four fixed condensers by means of a switch with dead end contacts. The autodyne generator is a reactance variometer using one or two valves in parallel and can be made suitable for any wavelength or loop aerial. Both reactance coils can be lengthened by a self-inductance.

Each piece of the receiver is mounted in a polished wood box with an ebonite top on which are mounted the valves, terminals and controls.

Decremeter Type "Delta."—This is a direct reading instrument (Fig. 4) which can be used as a wavemeter if desired. It is made up in portable form with carrying straps.

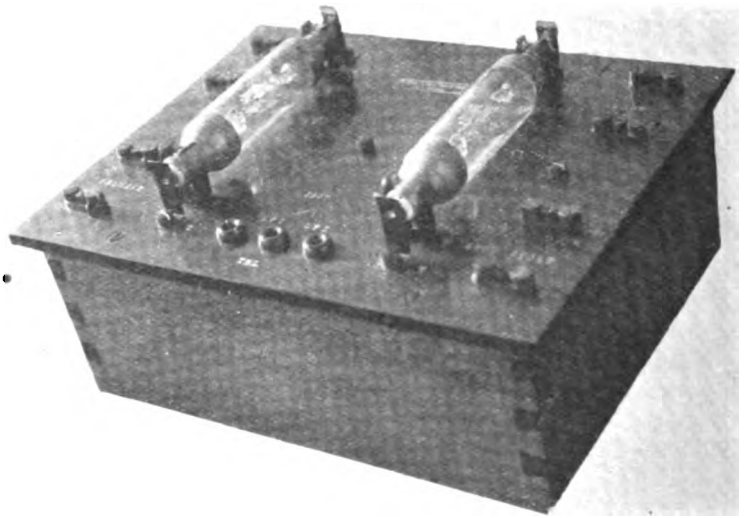

FIG. 6.—Two-valve Low-frequency Amplifier.

The translation of the reading on the scale is provided for by a curve which with a diagram of the set is fastened conveniently in the lid of the case.

Wavemeter Type "Standard."—This wavemeter shown in Fig. 5 consists of a variable condenser fitted with a precision reading pointer, an inductance of three ranges 200 to 800 metres, 500 to 1,800 metres and 1,200 to 3,600 metres wavelengths, a high note buzzer and a crystal detector.

The set is made up in portable box form with the inductance mounted in the lid. A patented feature is involved in the set, the inductance being wound free from capacity and the wiring such that the whole inductance is in use for all ranges.

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Low-frequency Amplifiers.—The amplifiers are of three types, "LFA,"

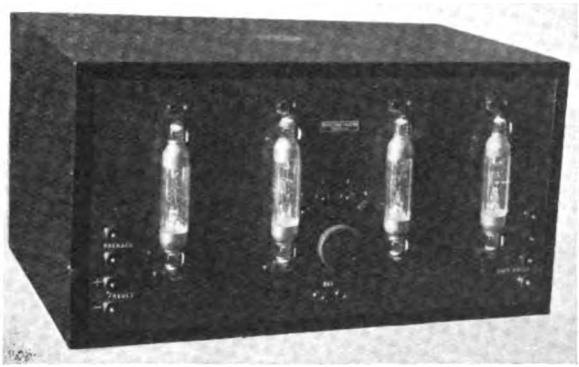

FIG. 7.—Four-valve Low-frequency Amplifier.

"LFB" and "LF." Type "LFA" is a single-valve amplifier and type "LFB" (shown in Fig. 6) a two-valve amplifier. They are fitted with a fixed potentiometer tapped correctly for Philips valves, this potentiometer being mounted in the box portion, while the whole of the rest of the fittings and connections are mounted on the top ebonite panel.

Type "LF" shown in Fig. 7 is of similar construction and detail and is designed in particular for use after the "Marine" type receiver. It is of the same dimensions as that set but has four valves and a dead end switch situated in the centre of the panel which puts into operation one, two, three or four valves without plugging over the telephones.

Short Wave Receiver Type "Torpedo."—This receiver (Fig. 8) is designed for wavelengths of 400 to 3,000 metres and is specially suitable for telephony

FIG. 8.—Short Wave Receiver.

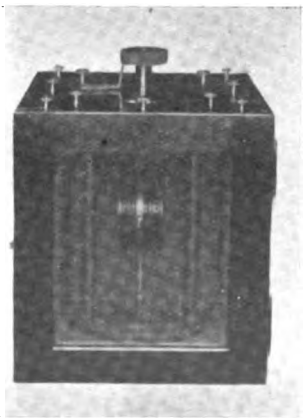

FIG. 9.—Direction Finder.

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reception. The various pieces are mounted on an ebonite panel sunk into a polished wood box. A variable condenser is supplied exterior to the set.

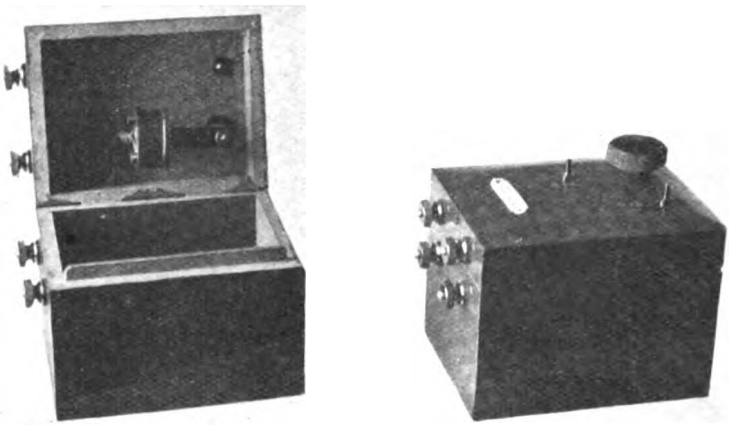

FIG. 10.—High Note Buzzer.

Direction Finder.—The Dutch military authorities employed this type of direction finder during the war (Fig. 9). It is constructed as a separate unit in a polished wood case with a glass front giving clear vision of the search coil the handle of which together with the necessary pointer and terminals are mounted on the top of the instrument.

High Note Buzzer.—Designed to form a constant high note buzzer this set contains an induction coil mounted in the lid and the circuit is made *via* this induction coil, the telephones and key in such a manner that the operating knob interrupts the induced currents while the buzzer is continuously in operation. Its current consumption is very small.

Fig. 10 shows the set with the lid both open and closed.

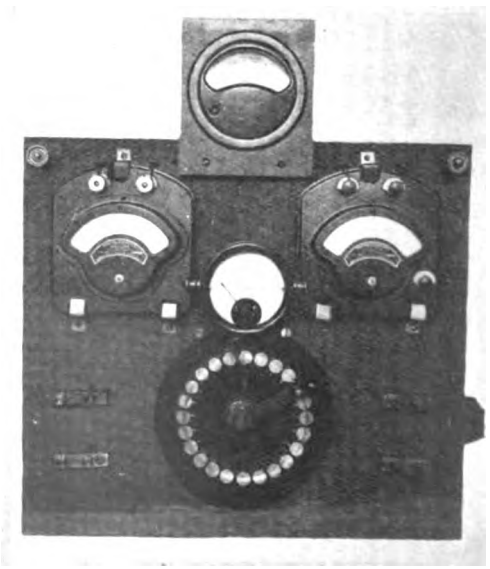

FIG. 11.—Small Telephone Transmitter.

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Small Telephone Set.—At present only in the experimental stage this set will be fitted up in a polished mahogany case with an ebonite front panel on which all the necessary connections and controls will be fitted. Fig. 11 shows the various components of the set which will consist of a variometer for the grid and plate circuit, coupling variable condenser, filament resistance,

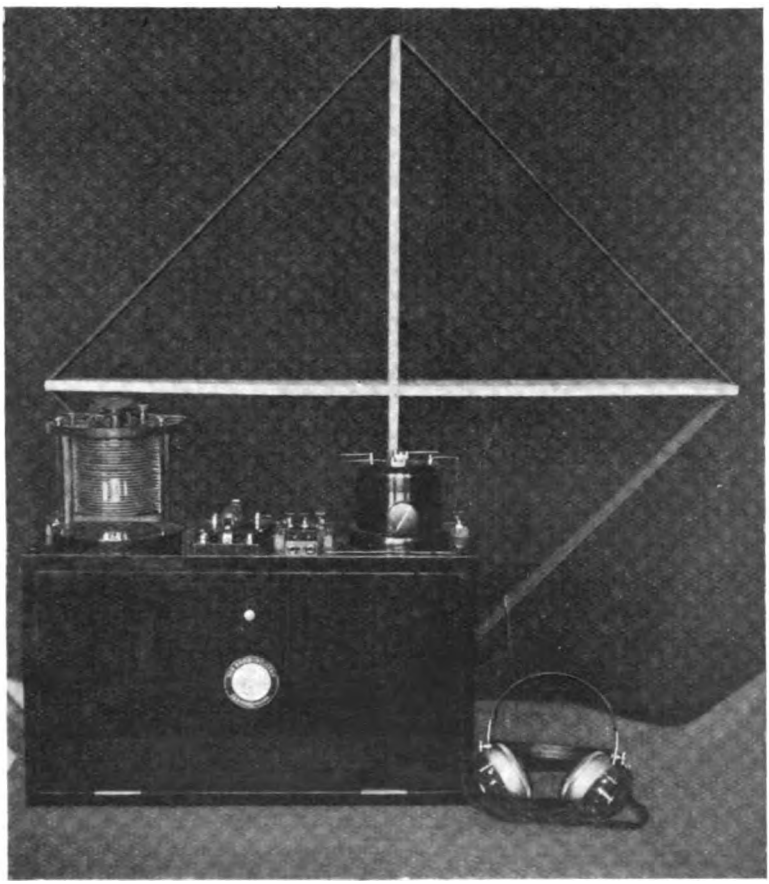

FIG. 12.—Loop Receiver.

valves 30 to 50 watt, aerial ammeter, plate milliammeter, filament voltmeter, earth aerial, high- and low-tension terminals and suitable contacts for a. microphone or key.

Loop Receiver Type "Tijdsein."—This set shown in Fig. 12 is specially constructed for the use of watch and clock makers for taking time signals

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and controlling and adjusting electric clocks, etc. It is suitable for wavelengths up to 3,000 metres.

The accumulator, anode battery and telephones can be packed up in the case, the lid of which is suitable for use as a writing desk.

Carborundum and its Rectification Effect.

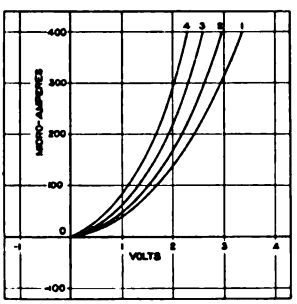
By H. M. DOWSETT, M.I.E.E., F.Inst.P.

(*Concluded from page* 594.)

(13) The following experiment which is related to the one just described was carried out at a later date using a plain solder-mounted crystal.

Current was passed through the steel spring to heat the point contact to various temperatures. The characteristic and the signal strength were taken for various temperatures of the steel spring up to 200° C.—the current then passing through the spring being 37 amperes.

The characteristic became steeper (Fig. 10) and the signal strength increased as the temperature rose and these changes were shown to depend solely on the temperature and not on the heating current as the signal strength only fell off in intensity as the crystal cooled down.



Curve.	Temperature of Contact Spring.
1	19° C.
2	60° C.
3	100° C.
4	200° C.

FIG. 10.—Effect of Temperature on Characteristic of Crystal mounted in Solder.

The audibility increased four times for an increase in temperature from 19° C. to 200° C.

(14) What happens when a carborundum detector loses its sensitivity due to heavy induction in the receiver circuit ?

If a sufficient D.C. voltage not exceeding 20 volts is applied to a crystal detector the current flowing through the point will heat it up, the internal resistance of the crystal will fall and there will be a progressive increase in current. When it exceeds 1 ampere the point will be red-hot. A suitably mounted crystal was heated up in this way, the minimum voltage being used for the purpose (see Fig. 11B). It was found on re-test when the crystal was again cool that its sensitivity as a detector had remained unimpaired, although the characteristic had altered as shown in Fig. 11A from A_1 to A_2.

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In this case the working current—which usually does not exceed 5 micro-amps—had been increased 250,000 times without burning the point or breaking it down.

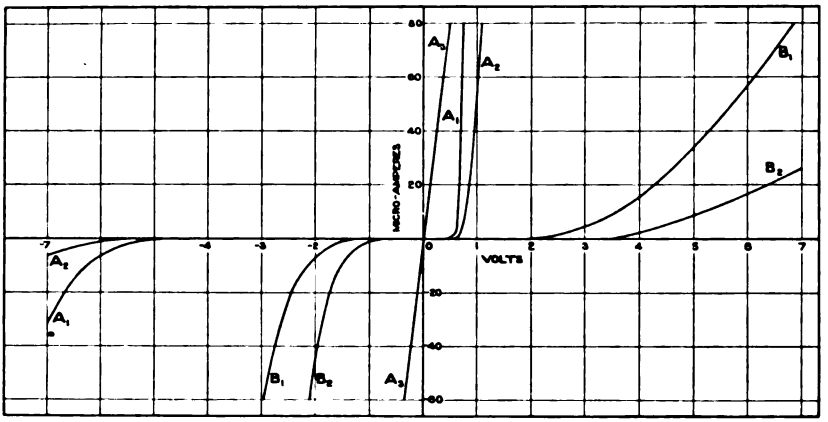

FIG. 11A.—Effect of passing Strong Currents through Carborundum Crystal.

GREEN CARBORUNDUM.

Curve A_1 = Characteristic before heating.
Curve A_2 = First test—Characteristic after heating to a dull red by current of 1·25 amps at 18 volts in the positive direction.
Curve A_3 = Second Test—Characteristic after again heating to a dull red by current of 1·25 amps at 24 volts in the negative direction.
After first test point of contact appeared unaffected by the heat.
After second test point of contact appeared slightly burnt.

BLACK CARBORUNDUM.

Curve B_1 = Characteristic before heating.
Curve B_2 = Characteristic after heating with 4·0 amps at 20 volts in the negative direction.

A further application of 24 volts in the reverse direction did succeed in destroying the point with signs of burning, but this only shows that the current required to produce breakdown by burning is so extremely high that no induction effect would have sufficient magnitude to produce it. As shown in Fig. 11A, A_3, the damaged point ceased to rectify and became conducting..

The effect of heating up a negative crystal is also shown in this figure. The characteristic was altered from B_1 to B_2 but the crystal still remained a good rectifier even when 4 amps had passed through the point contact.

But the momentary application of high voltage from a low-current source will often destroy the sensitivity of a detector. Thus various crystals broke

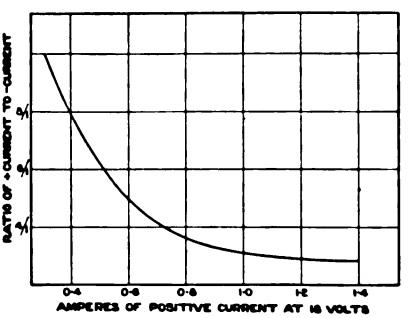

FIG. 11B.—Curve showing Ratio of Positive Current to Negative Current taken during First Heating Test on Green Carborundum Crystal.

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down after being flashed several times from a dry battery at voltages ranging from 60 volts to 200 volts, and also on the momentary application of 60 volts high frequency (see Figs. 12 and 13). In these cases the maximum current was within the values 0·01 to 0·04 ampere.

Under the microscope the damaged points either appeared to be fractured with no signs of burning, or the crystal had lost its lustre or become discoloured, and in a few cases there were signs of burning.

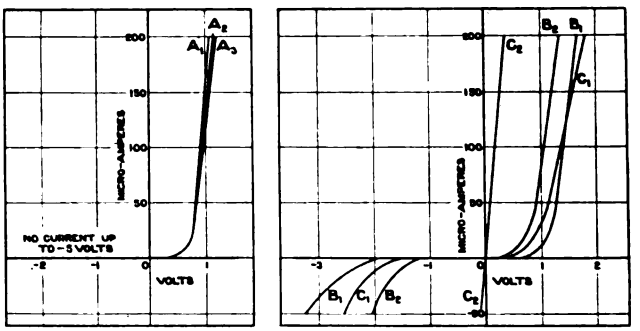

FIG. 12.—Effect of application of High Voltages to Crystal.

CRYSTAL WITH STEEL TIP AND MOUNTED IN SOLDER.

A_1 = Original characteristic.
A_2 = After application of 200 volts (dry battery) from plate to crystal opposing rectification.
A_3 = After application of 200 volts from crystal to plate assisting rectification.

CRYSTAL MOUNTED IN SOLDER ONLY.

B_1 and C_1 = Original characteristic.
B_2 = After application of 200 volts opposing rectification.
C_2 = After application of 200 volts assisting rectification.

The potential gradient is greatest at those parts of the layers of the crystal which enter into the rectification effect, and in the cases just quoted with the crystals still cold this gradient was unquestionably very high, so that there is little doubt that the manner of these breakdowns was by electrostatic disruption of the rectifying layers, which was followed in a few cases by burning owing to the sudden rise of current resulting from the great fall in effective resistance, and the possible presence of impurities.

(**15**) In all the experiments just described a large group of irregular crystals has been employed as a detector, but the conclusion has been reached that the only part concerned in rectification is contained within the thickness of the first crystal to which the point contact is made.

To carry the investigation further it would be useful to examine the behaviour of a single crystal.

It is practically impossible to separate out and mount a single crystal but we can arrive at a similar result by employing a group of regular crystals layered evenly one on the other and by making our contacts all on the same crystal of the layer.

One part of it must be steel tipped to ensure a stable low-resistance contact

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of reference, or a piece of carborundum may be chosen which has the layered crystal grafted well into another single group to which the tipping process can be applied and the results will be equally good.

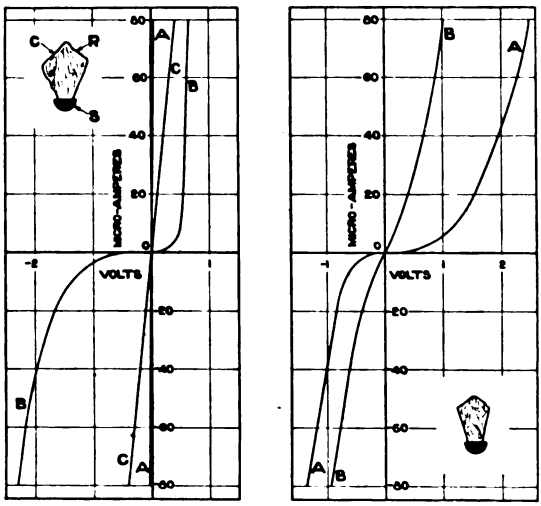

FIG. 13.—Effect of application of High Voltages and High-frequency Currents.

BREAKDOWN VOLTAGE FROM C TO R = 60 VOLTS D.C. FROM DRY BATTERY IN NEGATIVE DIRECTION.

Curve A = C to S before and after breakdown.
Curve B = R to S and R to C before breakdown.
Curve C = R to S and R to C after breakdown.

BREAKDOWN VOLTAGE = 60 VOLTS (APPROX.) HIGH FREQUENCY (WAVELENGTH = 600 METRES).

Curve A = Before breakdown.
Curve B = After breakdown by induction.

Using such a crystal having a width of face of about $\frac{3}{8}$ inch the first facts which can be established are that every perfect part of the crystal rectifies, and rectifies in the same sense. The rectification voltage and the effective resistance are lowest at a point and highest on a face. As much as 20 volts may be required to be applied at some places on a face to produce a detectable current while the nearest crystal point on this face may not require more than 0·2 volt.

It can also be shown that the internal resistances of crystals is inversely proportional to their size, the resistances measured from natural neutral points on green positive carborundum to the steel-tipped base of the large crystal formation having values between 200 ohms and 2,000 ohms and the small crystal formation having values 5,000 ohms to 10,000 ohms.

Also for black negative carborundum and large crystal formation 400 ohms to 1,000 ohms and small crystal formation 2,000 ohms to 10,000 ohms.

Neutral points produced by electrical breakdown covered a range that had a lower minimum and a much higher maximum than any value mentioned above.

The next fact which is illustrated by Fig. 14A is one of considerable interest.

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C_1 and C_2 are two neutral points at different distances from R the rectifying point and from S the steel-tipped base. The resistances through the crystal from C_1 to C_2, C_2 to S, and C_1 to S are all different, yet either of these three neutral contacts gives the same characteristic with R.

The same result was obtained with many other large crystals, the neutral points used being preferably natural to the crystal or were made artificially if required at a particular spot by fracturing the crystal.

The exceptions all gave higher resistance characteristics than that between the rectifying point and the steel-tipped base, as shown in Fig. 14B.

The only explanation one can offer of this effect is that when a rectifying point is being used and a certain intimacy of neutral contact is obtained, the crystal can be considered as having no internal resistance other than at the rectifying part.

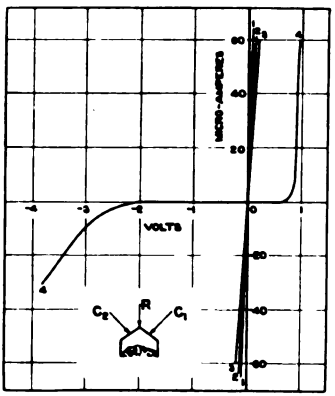

FIG. 14A.

Curve 1 = C_1 to S.
Curve 2 = C_2 to S.
Curve 3 = C_1 to C_2.
Curve 4 = R to S. R to C_1. R to C_2.

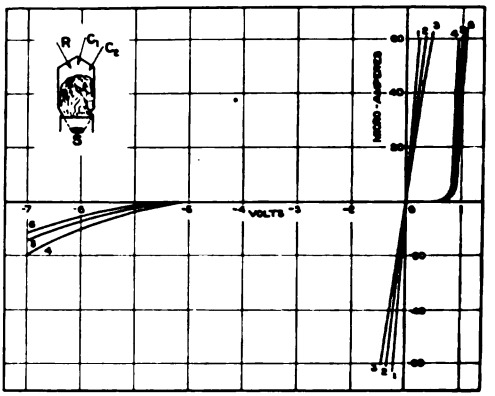

FIG. 14B.

Curve 1 = C_1 to S.
Curve 2 = C_2 to S.
Curve 3 = C_1 to C_2.
Curve 4 = R to S.
Curve 5 = R to C_2.
Curve 6 = R to C_1.

If this is so then it should follow that a change in contact pressure which is capable of making a considerable alteration in the resistance between two neutral contacts on a crystal, if applied to one of these contacts when it is being used with a rectifying point should make very little difference to the characteristic.

This was confirmed. Pressures varying from less than 100 grammes up to 2,500 grammes caused a change in resistance measured through the crystal of 500 ohms down to 100 ohms in one case, but there was no corresponding effect on the characteristic.

The effect noted in section (5), that the steel tip could be removed and replaced by solder and the original solder characteristic could then be reproduced is obviously related to the phenomena just described.

Also it is because of these results one must conclude, as intimated in

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section (9), that it is not entirely because the steel has a better mechanical grip on the crystal than the other metals employed that it gives the best results.

A further case of interest which may be quoted is that of a large green crystal on the face of which a rectifying point contact had been established instead of at an edge.

The application of 200 volts slightly altered the characteristic but did not destroy the rectification effect. A certain amount of heat developed however which caused a flow of fluid between the outer crystal layers and the crystal became more transparent. This fluid would necessarily consist of the constituents of low melting point, the impurities, and as the rectification effect remained still good the conclusion is that these impurities have no useful function near the point contact.

It would also appear from this result that the presence of certain kinds of impurity does not prevent the formation of a perfect carborundum crystal, and if iron when applied in the molten state to the crystal finds its way between the layers without fracturing them, this would provide the most reasonable explanation of the improvement which results from steel tipping.

With this crystal the blue glow which can often be seen when the applied voltage is high enough, started at a short distance from the point contact, was fan shaped, and also appeared to be located between the layers.

These effects would appear to indicate that there is an easier molecular and electric flow parallel to the faces of the crystal than normal to them.

(16) All the phenomena described are consistent with the following theory of the rectification effect as exhibited by carborundum.

Normal conductivity takes place parallel to the faces of the crystal so that for a non-rectified current flow from any point A to the base B (Fig. 15) the

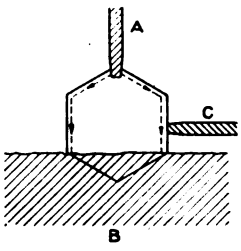

FIG. 15.

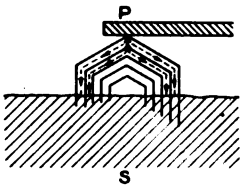

FIG. 16.

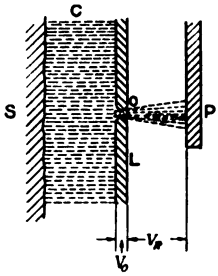

FIG. 17.

crystal edge must be broken at A to establish a connection in line with the direction of flow, a condition which is attained at B by establishing an intimate contact of wide area.

But a current cannot flow through the crystal from a contact C normal to a face without the molecules forming the crystal being strained apart at this contact in order to provide an opening to introduce or extract the necessary

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electrons. When the applied E.M.F. reaches a certain value the equivalent of an orifice is opened into one or more of the outer layers of the crystal against an opposing elastic pressure resisting distortion which is felt throughout the crystal, in the same way that mechanical pressure is felt throughout an incompressible fluid, so that no matter how far or how near the neutral contact may be to the rectifying point, the effective resistance through the crystal and therefore the characteristic will be the same.

If the elastic disturbance is not carried to an extreme the orifice closes and the crystal recovers as soon as the applied E.M.F. driving the current is removed.

A contact at a perfect edge or still more at a perfect point of a crystal requires a smaller applied E.M.F. to strain an opening into the crystal structure than a contact on a face.

The first flow of current takes place through the outer crystal layer only (Fig. 16); then as the applied E.M.F. is increased an entry is forced into one or more inner layers until with a sufficient further increase of applied E.M.F. the whole crystal conducts.

It is the successive layers coming into circuit which cause the bend in the characteristic, the straight part being obtained when they are all conveying current.

Because the smaller crystals have fewer layers their resistance is higher than that of larger crystals.

Crystals which have a high rectification voltage have many layers through which an elastic opening must be made before the layer is reached which is in good electrical contact with the base electrode. For this reason the small crystals from the base of a block of carborundum which are practically all faulty, on the average have a higher rectification voltage than the more perfect large ones from the top. A crystal ceases to grow as soon as it becomes faulty, and most of the impurities are found at the base of the block.

In Fig. 17 the plate on the rectifying point of the crystal is represented by P, the rectifying layers by L through which an orifice O is opened into the elastic electrostatic and magnetic fields of the crystal C by the application of the E.M.F. V_0.

This allows a current to flow from the steel-tipped base S to P as indicated by the jet LP which will have a value depending on the size of the orifice representing the number of crystal layers tapped, the specific resistance of the crystal for normal currents, and the applied E.M.F.

Owing to the elastic pressure existing in C, for every electron taken in or expelled at O another leaves or enters at S and there is no resistance loss therefore in conveying the current from O to S or *vice versa*, provided the crystal structure is only strained and not broken at O. The whole potential drop in the crystal due to resistance therefore occurs in the rectifying layers and can be represented by V_R.

If V_0 and V_R represent the total absorption of E.M.F. in the crystal there is nothing to prevent the current being subject to Ohm's law, and if these two values can be separated we can write $I = \frac{V_R}{R}$.

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(17) Much additional information can now be obtained from the current voltage characteristic, such as curve A, Fig. 18, which is the working or positive half as given by a positive crystal.

It may be divided into three distinct sections. In the first the E.M.F. applied to the crystal can be increased up to a certain value without current flowing, the crystal behaves in fact like a very small condenser having a capacity which is however too small to measure, and the whole of the E.M.F. is applied in straining the crystal.

In the second section there is a flow of current the rate of increase of which becomes greater as more crystal layers open, and the applied E.M.F. is divided in varying proportions between straining the crystal and driving the current through the layers. The third section of the characteristic begins when all the layers are open so that the E.M.F. straining the crystal has reached a constant value and the characteristic has therefore become perfectly straight, the increase in current being proportional to the increase in applied E.M.F.

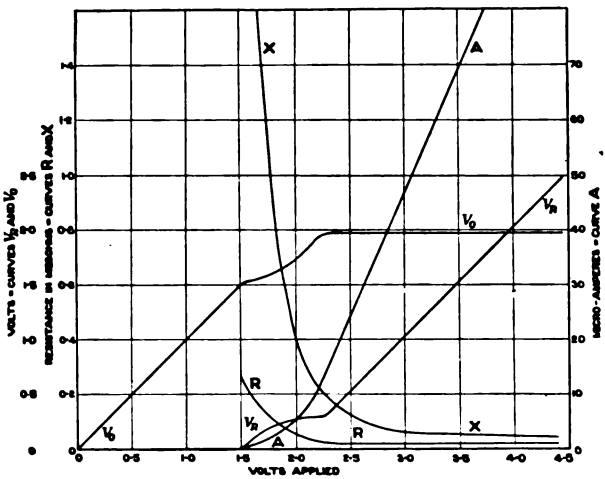

FIG. 18.—Positive Portion of Characteristic of Positive Crystal with Calculated Resistance Curves.

From the slope of the characteristic at every point we can then calculate the true resistance of the crystal.

This is shown by the curve R, which may be compared with curve X giving the apparent resistance obtained by dividing the applied E.M.F. by the resultant current, and which never reaches a constant value.

The E.M.F. expended in driving the current through the crystal V_R, is given by the product of the current I and the true resistance R at that current, and the values obtained are plotted in curve V_R.

The difference between the applied E.M.F. and V_R is V_0 the E.M.F. used in straining the crystal and these values are plotted in curve V_0.

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If it is required to separate V_0 from V_R without working out the actual values of R it can be done in a very simple manner as follows :—

For any value of applied E.M.F. draw the tangent to the characteristic at the corresponding point, then where it cuts the abscissa it will divide the applied E.M.F. in the required manner, the part towards zero being the orifice voltage V_0 and the remainder V_R.

The most interesting portions of the curves V_0 and V_R are the peculiar bends which take place during the process of straining open the crystal. Usually the last layers, those at the centre of the crystal, appear to open with a rush as the final rise of V_0 to its steady value becomes fairly steep, and this causes the E.M.F. driving the current to stop increasing or even to fall as shown in curve V_R, Fig. 19.

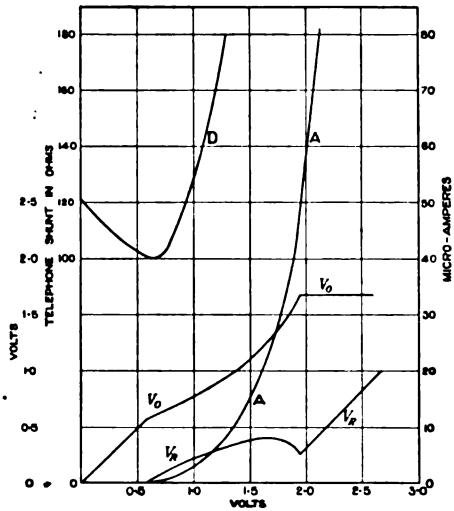

FIG. 19.

Curve V_R = Resistance component of voltage.
Curve V_0 = Valve component of voltage.
Curve A = Characteristic.
Curve D = Telephone shunt for just audible signals.

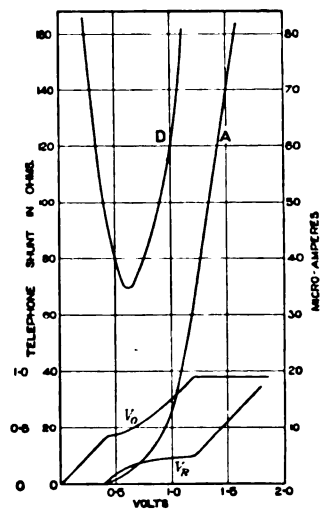

FIG. 20.

Curve V_R = Resistance component of voltage.
Curve V_0 = Valve component of voltage.
Curve A = Characteristic.
Curve D = Telephone shunt for just audible signals.

The best rectifying point as shown by the shunted telephone method (see curves D, Fig. 19 and Fig. 20) occurs near the commencement of these bends and apparently where the increment of E.M.F. divides more or less equally between V_0 and V_R as the curves at this point are approximately parallel.

The crystals vary in the number of layers and the critical voltage per layer, so that for different crystals these curves differ considerably in detail although they all have the same general form.

(**18**) There remains finally to picture a structure of the atoms and molecules forming the carborundum crystal which will be consistent with all the experimental results described and with the theory of the rectification effect as put forward in section (**16**).

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If possible this structure should explain why the crystals are electrically polarised so that they act as normal conductors having a few hundred ohms resistance for currents flowing parallel to the crystal faces, whereas at right angles to these directions an E.M.F. has to be applied to force an elastic opening into the path or paths parallel to the crystal faces, which opening has a very high resistance (of the order of 250,000 ohms down to 20,000 ohms) until its elastic limit is exceeded.

An explanation is also required of the second polarisation effect, why all the crystals of green carborundum find it easier to receive electrons than to give them up, and all the crystals of black carborundum find it easier to give up electrons than to receive them. And, finally, some definition is necessary of the nature of the elastic medium which is active when the crystal is rectifying, but quiescent when a normal current is passing between neutral points.

As regards the first query, the arrangement of atoms in crystals can be determined by the method of X-ray analysis so ably developed by the Braggs.

Carborundum has not yet been submitted to this process but from the general results obtained with other hexagonal crystals we know that the carbon and silicon atoms must be symmetrically placed relative to each other on some form of hexagonal space lattice structure, but no experimental method has yet succeeded in showing how these atoms are bonded together.

If current flows without much difficulty along the layers but has to be forced through them, it seems probable that in the first case the current is carried by electrons which are under very little constraint, whereas in the second case they have to be displaced from tied positions such as are held by bonding electrons.

As regards the second point we start from the facts that the crystal as a whole is electrically neutral, and that silicon is electrically positive to carbon.

The work of the Braggs already referred to has shown the agreement which exists between the close packing of spheres and the positions of atoms in crystals, and may therefore be accepted as evidence that the external shape of the atom is either spherical or spheroidal.

Rutherford has shown that the seat of all the measurable positive charge, and therefore of practically the whole atomic mass, occupies only a very small space at the centre of this spheroid.

In a neutral molecule, then, the essential parts or nuclei of the two ions are as far apart as the centres of two touching spheres so that when an electron current—that is a stream of negative ions—flows through such a molecule it will enter the positive ion first.

We may therefore conclude that in the positive crystal the electron current finds it easiest to leave the steel plate and enter the carborundum crystal through a silicon atom, and in the case of the negative crystal the electron current finds it easiest to leave the carborundum for the steel plate by way of a carbon atom.

It may be suggested that the negative charge of the carbon does not completely satisfy the silicon in the first case, and more than satisfies it in the second, but this would cause the two types of crystal to have resultant charges whereas they are perfectly neutral.

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Or again it may be suggested that the silicon is nearest to the crystal surface in one case and carbon in the other, but the probability is that they are more or less equally scattered over it.

The most reasonable view is that conductivity depends on the orientation of the molecules, that normally the conducting axes of the molecules are all in the planes of the crystal faces, and that when a current flows through a rectifying point the axes of the nearest molecules have been deflected through a small angle with the silicon ends up in order to receive it in green carborundum, a similar change in orientation taking place but with the carbon ends up when the black carborundum transmits an electron current to the steel plate.

(19) To answer the last question we must examine the particular structure of atoms and molecules.

Although many different models of the atom have been suggested, the collective opinion of physicists at the present time is not definitely in favour of any one of them.

There is a distinct leaning towards that developed by Lewis and Langmuir, but this model is too incomplete to be helpful in the present case.

It deals with the possible arrangements of electrons surrounding the positive charge, but it is not concerned with the electrostatic and magnetic fields which, until we have definite proof to the contrary, must be assumed to accompany them and to play a very active part in the life of the atom. These fields necessarily must occupy the greater part of the space in the atomic volume, and we must look to them to provide the elastic medium in the crystal of which the rectification effect gives evidence.

The model described below is an attempt towards a more complete presentation of the atom based on the electromagnetic theory.

The nuclear part of it was outlined by the author during the discussion of Mr. S. Evershed's paper on "Permanent Magnets" read at the Institution of Electrical Engineers in May last year.*

(*a*) The positive electricity at the centre of the atom has the form and nature of a single vortex ring (P, Fig. 21), somewhat similar to the Kelvin ether vortex atom. It is built up of a number of units corresponding to the atomic number of the element concerned.

(*b*) Surrounding this ring are one or more dense shells of electrons (N, Fig. 21) also in vortex motion. The individual electrons in the shells move always so as to approach the positive electricity, if the ring moves clockwise round its axis the electron shell or shells move counter-clockwise, if the twist of the ring vortex motion is clockwise the vortex motion of the electron shell or shells will be counter-clockwise, so that the motions of the two kinds of electricity are therefore in opposite sense.

(*c*) The charge of the positive ring is utilised partly in balancing the mutual repulsion exerted by all the shell electrons and partly in constraining them to move in vortex motion round the ring.

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* *Journal of the Institution of Electrical Engineers*, 58, p. 827, September, 1920.

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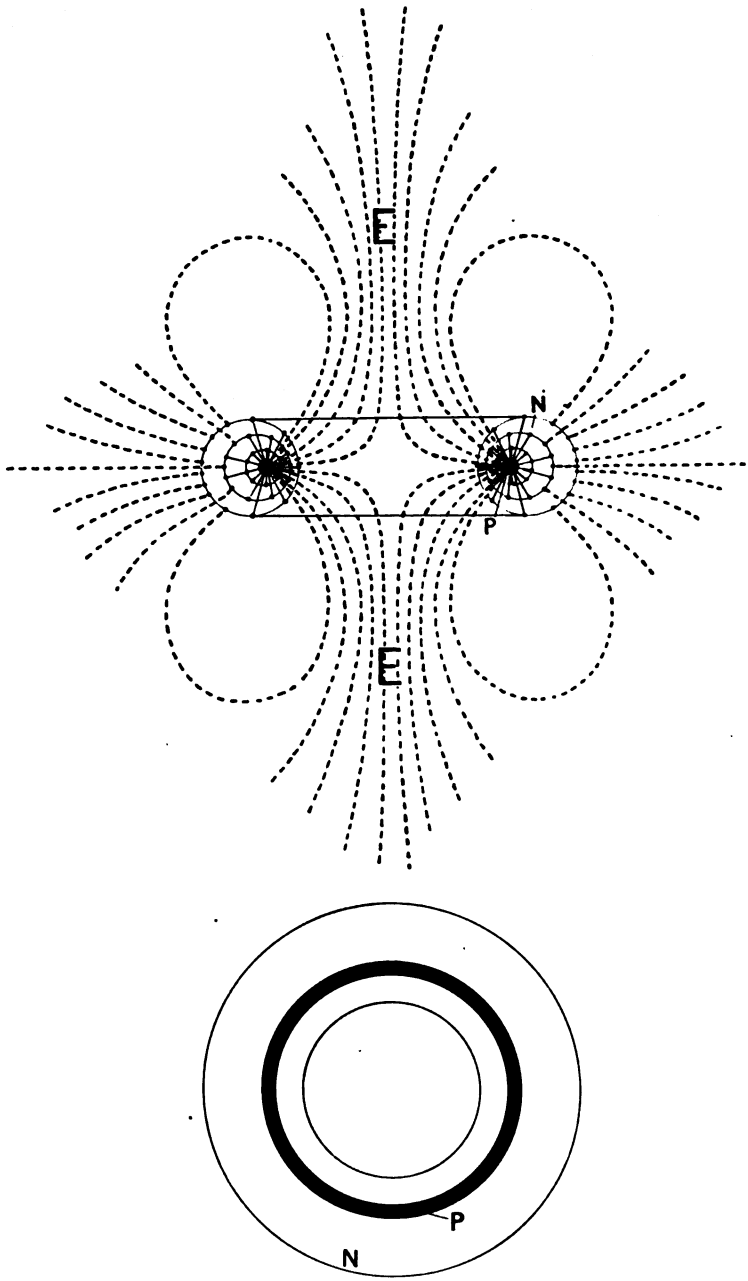

FIG. 21.—Vortex Structure of Atom.

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(*d*) The positive ring is not in the true centre of the electron shells. Normally it is nearest to the shell electrons as they pass through the

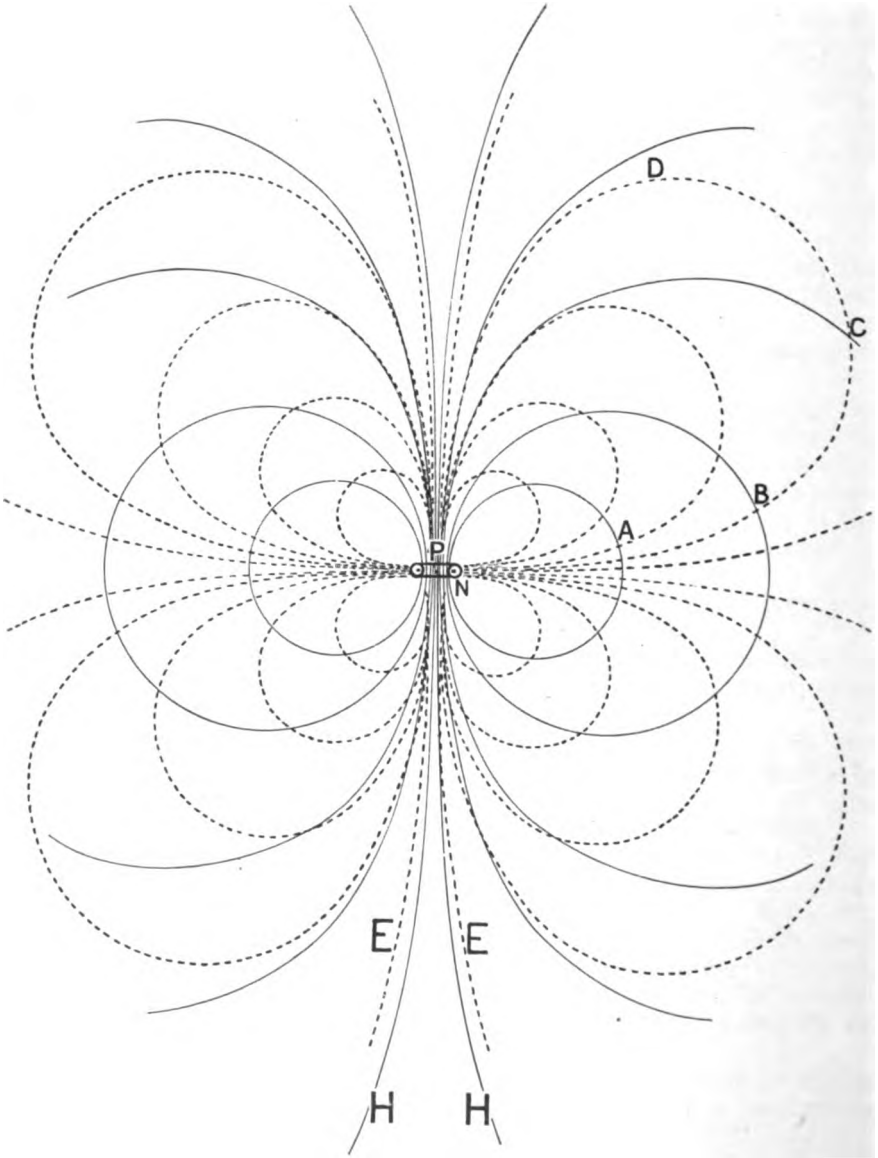

FIG. 22.—Magnetic and Electrostatic Fields round Vortex Atom.

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aperture of the system. As a result these inside electrons speed up and open out, while the outside electrons slow down and close up, so that on the extreme diameter one shell tends to screen the next outside it from the direct action of the field from the positive ring.

This field (E, Fig. 21) therefore leaks out towards the atomic axis and links up externally with the weakly held electrons from which it is partially screened internally, so that the ring system core of the atom is enveloped in an extensive and re-entrant electrostatic field, and the shape of the atom as a whole therefore approximates to a spheroid.

(*e*) The strength of the electrostatic leakage field (E, Fig. 22) is proportional to the atomic number of the element, and is the positive charge which is measured on the atom. For distances near the core its intensity falls off according to the inverse square law in agreement with the experimental results of Rutherford and Chadwick.

(*f*) The vortex motion of the positive ring produces an internal magnetic field which is balanced by the opposite vortex motions of the electron shells. Also the external magnetic field produced by the revolution round its axis of the positive ring, is counterbalanced by the revolution in the opposite sense of the electron shells, so that the system as a whole tends to have no resultant magnetic field in space.

With most of the elements this magnetic balance is not perfect so that the atom has a small resultant magnetic field in space (H, Fig. 22).

(*g*) The effect of the compound electrostatic-magnetic field surrounding the core on any stray electron is to draw it towards the core. But its progress there will not be direct. The magnetic field will cause it to spiral, and at certain positions on its path the resultant of E and H may even give it a fixed orbit.

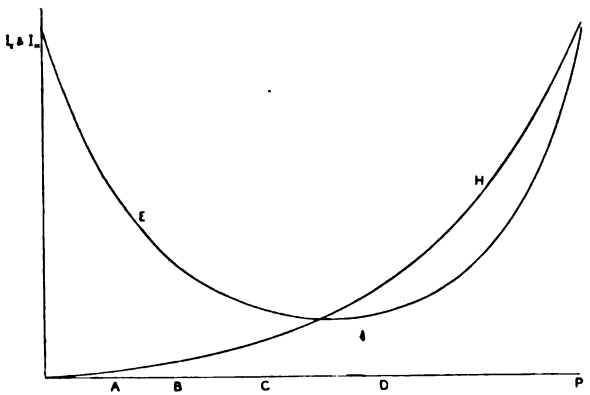

FIG. 23.—Variation of Magnetic and Electrostatic Fields acting on Electron in various positions round Vortex Atom.

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Imagine a free electron to travel from the outside of the atomic core towards the core aperture following the path NABCDP (Fig. 22). Then the intensities of the E and H fields through which it will pass are roughly indicated in Fig. 23.

From N to some point B the intensity of the electrostatic field commences high but steadily falls, and the magnetic field is so weak that it only introduces a very small component of motion at right angles to the directions of both fields, which will carry the electron out of the plane of the paper to some position normal to it.

From B to a point about midway between C and D the electrostatic field falls to a minimum while the intensity of the magnetic field steadily increases.

This means that the component of motion in a plane normal to the paper becomes relatively much stronger, and the deviation may be so considerable that the electron is carried a negligible distance nearer to P for a complete circuit round the atom.

About the region CD while the electrostatic pull is almost constant, the deviation effect of the magnetic field increases the nearer the electron is to P so that there exists hereabouts a tendency for the electron to be given a permanent orbit.

While the electron is in orbital motion in the region CD it is a "valency" electron, capable of being held by the fields of two neighbouring atoms and by the same means assisting to hold the two atoms together. In such a position when necessary it may even be stationary relative to the two atomic axes, but it will still be in relative movement to both atomic cores owing to their rotation.

Tetravalent atoms like carbon and silicon have two such electrons at each pole.

(*b*) The E curve becomes steeper than the H curve near the atomic axis, and the two fields gradually become more parallel, so that should the balance be disturbed which keeps the electron within the orbital region, on passing D it will be sucked into the aperture of the atom at P, where, if there is room for it, it will remain spiralling in and out.

There are then two positions of stability for the electron in the atom: (1) in a valency orbit, (2) in the aperture, and every neutral atom is accompanied by a definite complementary number of loose electrons divided between these two positions. The elements in group 0 have no valency electrons.

A current flows when either a valency electron or an aperture electron is displaced and its position is taken by another one, and as the aperture electron is under very little constraint from the magnetic field it can be moved by the application of a smaller E.M.F. than is required to displace a valency electron.

(*i*) When two atoms of different elements which each have a resultant magnetic field, unite to form a molecule, they will come together as do permanent magnets in such a way that these fields assist each other. But the leakage electrostatic fields must oppose each other.

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The molecular fields will then have the general form shown in Fig. 24; they will intersect at right angles where the atomic electrostatic fields meet, and the valency electrons will have their orbits in this plane.

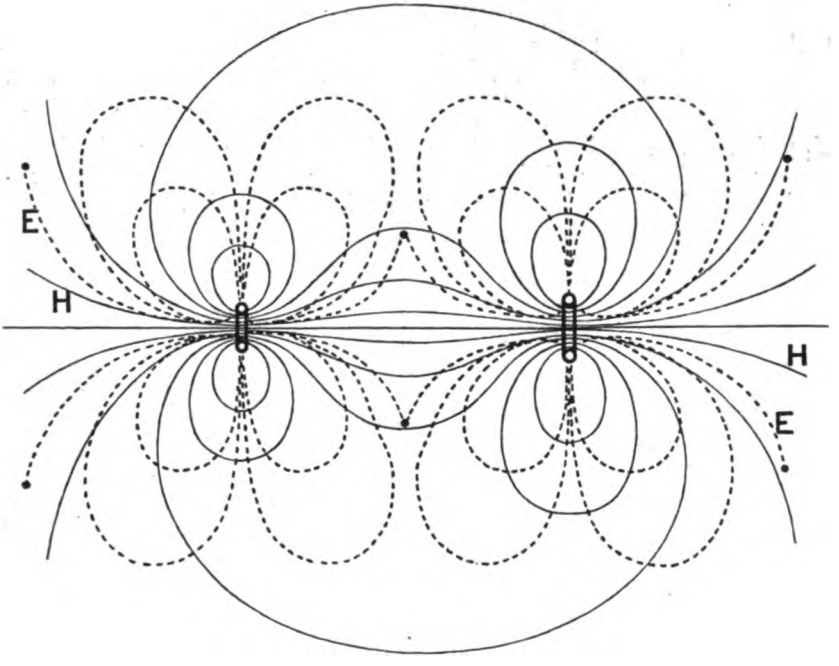

FIG. 24.—Molecular Fields.

In the production of the carborundum molecule **CSi** (Fig. 25) two electrons have been given up; there are two electrons in a common orbital region which are shared between the two atoms and two at each end orbital region. In this figure the diameters of the two elements have the same relative values as the atomic diameters given by W. L. Bragg.*

(*j*) In the process of crystal structure many molecules form chains of various types, positive ion of one to negative ion of another, and the two end valency electrons of one carborundum molecule share their fields with other carborundum molecules so that the molecules become bonded together.

In the complete crystal then there are sufficient valency electrons to provide for the independent existence if necessary of each molecule, but there are not sufficient to provide for the separate existence of

* *Philosophical Magazine*, 40, p. 180, August, 1920.

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each atom. The bonding therefore between the molecules will be much weaker than between the atoms.

It is not necessary for our present purpose to follow this theory further. It is clear that on the application of an E.M.F. a molecule having the form described will pass an electron current from X to X_1 without any difficulty by drawing on the aperture electrons; but if the E.M.F. is applied from Y to Y_1 no current can pass until the imposed electrostatic field has reached such a value as to disturb the stability of the valency electrons.

For the reason given above it is the valency electrons between the molecules such as those at Z and not those at the centre of the molecule in the plane YY_1 which will be the less difficult to displace, and in effecting this displacement and the loosening of the crystal bonding the imposed field must unquestionably alter the orientation of some of the molecules.

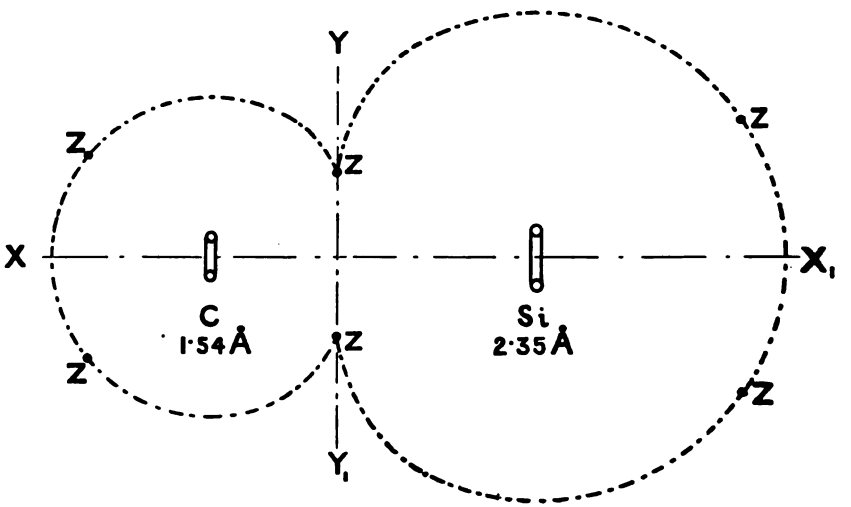

FIG. 25.—Structure of Carborundum Molecule.

Also it is clear that the displaced valency electrons will tend to travel along the XX_1 axis instead of along YY_1 if the two paths finally join, and as the orbital stability in **C** and **Si** is not necessarily the same, and it must be affected by the form of the space lattice structure, it is reasonable to expect that the applied E.M.F. will always establish conductivity more easily through the carbon end of the molecule in one type of crystal, and more easily through the silicon end of the molecule in another type of crystal, the disturbance changing the orientation of the molecule as a whole, however, not only of one or other atomic part.

Further, this molecular distortion involves the stability of the crystal as a whole and is resisted by the combined magnetic and electrostatic molecular fields as a whole, so that when stability is yet more disturbed by forcing

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electrons in or taking them out at a rectifying point, an elastic pressure due to these fields is felt throughout the crystal, and electrons will be forced out or sucked in at any other point without energy being lost between the points of ingress and egress.

A current which passes between two neutral points on a crystal involves aperture electrons only and no change in the orientation of molecules, so that there is no reaction in the crystal tending to neutralise the internal absorption of energy.

The principle on which the rectification effect in carborundum appears to be based has now been stated.

To follow out its operation in greater detail requires a more complete knowledge of the space lattice structure of the two principal forms of crystal than we at present possess.

All the experiments described in this paper have been carried out at various dates in the testing laboratories of Marconi's Wireless Telegraph Company at Chelmsford, and in this connection the careful work of Mr. M. F. Willis, B.Sc., deserves special mention.

Notes.

Personal.

Dr. Lee de Forest, for many years the head of the de Forest Radio Telephone and Telegraph Company, resigned on September 26th as its active head. For the next few years he intends to reside in Germany. **Mr. Chas. Gilbert**, who has been treasurer of the company since 1915, has been elected its president and general manager. He will be assisted by **Mr. R. M. Keator**, who will have charge of sales and manufacture. [4368]

Dr. G. W. O. Howe, D.Sc., M.I.E.E., head of the Department of Standards and Measurements at the National Physical Laboratory, Teddington, has been appointed to the newly-founded James Watt Chair of Electrical Engineering in the University of Glasgow. [4252]

"Sir Charles Bright and Partners" is the style of a new firm of consulting engineers which has recently been formed, its members comprising Sir Charles Bright, F.R.S.E., M.Inst.C.E.; Mr. A. Hugh Seabrook, M.I.Mech.E., M.I.E.E.; Mr. A. J. Stubbs, M.Inst.C.E., M.I.E.E., and Lieut.-Colonel H. W. Woodall, C.I.E., M.Inst.C.E. [4237]

Commercial and General.

AN ITALIAN MARCONI COMPANY.—We have been informed that the notices that have appeared in the technical press recently with regard to the formation of an Italian Marconi Company are without foundation, as no such company has been formed. [4234]

CHINESE-AMERICAN WIRELESS AGREEMENT.—The American Minister in Peking has notified the State Department of the signing of a supplementary agreement between the Federal Wireless Company and the Chinese Government. The agreement relates to the issue of bonds for financing the project. [4322]

RADIOTELEPHONY BETWEEN FINLAND AND SWEDEN.—The directors of Sodra Finlands Interurbana Telefon A.B., of Helsingfors, have made application to the Finnish Ministry for Communications for the grant of a concession for the establishment of a system of radio-telegraphy between Finland and Sweden for general public use. According to the company's statement, it is proposed to form a separate company, in which the Finnish State would have the opportunity of being represented, for the execution of the scheme. [4408]

NEW BELGIAN WIRELESS STATION.—A powerful wireless station is to be erected at Ruysselde in Belgium; the tower is to have a height of 325 metres. [4420]

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IMPERIAL WIRELESS CHAIN.—H.M.S. *Raleigh* arrived at St. John's, N.F. recently on a visit of inspection of the Admiralty wireless station with a view to its utilisation as a link in the Imperial Wireless Chain. [4235]

NOTES ON WORKING OF ARC SETS ON S.S. "CARONIA" AND "SCYTHIA."—The *Caronia* is fitted with a 10 kW arc set, and the *Scythia* with a similar 5 kW installation. Power is derived from a motor generator set mounted on the upper deck and controlled from the wireless cabin.

After difficulties of adapting these sets to conditions of working on board ship had been overcome, both have given extremely satisfactory service. Very little difference has been experienced in the ranges obtained in working coast stations due to the fact that the *Caronia* is limited in her performance to the ranges of the stations with which she works, as they have not sufficient power to transmit to her as far as they can receive her. Reports indicate that good signals have been received from the *Caronia* at a range of 3,500 miles.

Traffic is handled with ease at 2,200 miles both with Devizes and stations on the American side, whilst traffic has been worked at ranges of 2,500 miles with Bar Harbour, Maine, U.S.A. Traffic can be dispatched very rapidly at these extreme ranges on account of the fact that signals are sufficiently strong to permit of batches of as many as twenty messages being sent. Although it takes approximately sixteen seconds to start up the arc, working assumes a higher rate of messages in a given period over valve sets of less power, which, through necessity of sending messages singly or in small batches due to weaker signals, lose the advantage of more rapid change over from send to receive. [4453]

WIRELESS TELEGRAPHY IN ITALY.—The first meeting of the Commission recently nominated by the Associazione Elettrotecnica Italiana to study questions related to telegraphy, telephony, and radiotelegraphy was held in July, when the use of wireless telegraphy by industrial companies possessing electric plant was discussed as one among several means of extending the employment of wireless telegraphy generally. In Italy hitherto wireless telegraphy has been limited to the naval and military services and to a few shipping concerns. To carry out the Association's plans three sub-committees have been appointed, whose duty will be to find out the machines best suited for wireless purposes, to fix standards for the various parts, to ascertain what dielectric rigidity is required, to settle the earth insulations of dynamos and transformers, the choice of a direct-current type of machine able to work with sudden and frequent changes of load, the tendency of short-circuiting and sparking at the collector, the insulation of conductors, protection against lightning, safeguarding of neighbouring networks against disturbance, etc. [4157]

Review of Radio Literature.

1. Abstracts of Articles and Patents.*

(F.) Thermionic Valves, and Valve Apparatus.

(6) APPLICATION OF VALVES TO OSCILLATION GENERATION (including Valve Transmitting Apparatus).

2674. **B. Rosenbaum** [E. F. Huth Gesellschaft]. Wireless Transmitting Apparatus. (*British Patent* 149216, July 12th, 1920. Convention date July 21st, 1917. Patent not yet accepted.)

* Particulars of the U.S.A. Patents abstracted in this section have been supplied by Mr. John B. Brady, Patent Lawyer, Ouray Building, Washington, D.C., U.S.A.; and those of the French Patents by Messrs. J. E. Raworth & Moss, Patent Agents, 75, Victoria Street, London, S.W.

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In a system for the transmission of undamped oscillations, feeble independently generated oscillations are impressed upon and amplified by one or more power valves before transmission to the aerial.

2675. **Gesellschaft für drahtlose Telegraphie.** Wireless Telephone Transmitter. (*British Patent* 158901, February 8th, 1921. Convention date February 9th, 1920. Patent not yet accepted.)

An addition to *British Patent* 154181.

2676. **Gesellschaft für drahtlose Telegraphie.** Wireless Transmitting Apparatus. (*British Patent* 159463, February 21st, 1921. Convention date February 28th, 1920. Patent not yet accepted.)

In a thermionic valve transmitter the grid potential is derived solely from the aerial current and is not influenced directly by the field of the plate inductance. The grid and anode connections are taken to tapping points on the aerial tuning inductance, so that the power output may be easily varied by changing the tapping point of the grid lead without changing the aerial tuning.

2677. **E. F. Huth Gesellschaft.** Thermionic Oscillation Generators. (*British Patent* 157928, January 10th, 1921. Convention date July 24th, 1919. Patent not yet accepted.)

In order to overcome the interference effects that normally occur when two or more thermionic oscillation generators are connected with their output circuits in parallel, each valve is caused to influence the other reciprocally by appropriate intercouplings.

2678. **L. Lévy.** Thermionic Valve Oscillation Generators. (*British Patent* 160799, March 24th, 1921. Convention date March 29th, 1920. Patent not yet accepted.)

Relates to an arrangement of two valves having retroaction provided by capacities and resistances only as used for the generation of large number of harmonics. A definite fundamental frequency with few harmonics may be generated by including a tuned loop in one of the valve circuits.

2679. **Gesellschaft für drahtlose Telegraphie.** Thermionic Oscillation Generators. (*British Patent* 160819, March 30th, 1921. Convention date March 31st, 1920. Patent not yet accepted.)

Relates to the use of A.C. of high audible frequency to supply the anode circuit of an oscillating valve.

2680. **W. H. Eccles** and **J. H. Vincent.** Generating High-frequency Oscillations. (*British Patent* 162067, January 21st, 1920. Patent accepted April 21st, 1921.)

Mechanical means are provided so that the filament current is adjusted when the reaction coupling is altered to ensure constancy of the generated frequency.

2681. **Société anonyme pour l'Exploitation des Procédés M. Leblanc-Vickers.** Converting Electric Currents. (*British Patent* 155784, December 23rd, 1920. Convention date December 23rd, 1919. Patent not yet accepted.)

Relates to a valve filled with an inert gas or vapour and having an incandescent cathode, one or more anodes and a grid electrode. Its applications to oscillation, generation and frequency changing are dealt with in the specification.

2682. **L. A. Hazeltine.** Producing Electric Oscillations. (*British Patent* 155789, December 23rd, 1920. Convention date November 28th, 1919. Patent not yet accepted.)

Relates to means for improving the efficiency of valve oscillation generators and for eliminating harmonics by the use of two or more valves simultaneously.

2683. **C. L. Farrand** [Marconi's Wireless Telegraph Company]. Valve Transmitters and Receivers. (*British Patent* 145039, June 14th, 1920. Convention date June 14th, 1919. Patent accepted July 14th, 1921.)

The grid circuits of valve used for transmission or reception are supplied from independent sources of H.F. of frequency generally differing from the wave frequency. For transmission a modulation method similar to the " choke control " method is described but using a transformer between the two plate circuits in place of a common choke coil, and having the grid circuit control or L.F. amplifying valve also supplied with a H.F. E.M.F. derived from a coil coupled to the aerial.

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2684. **C. L. Farrand** [Marconi's Wireless Telegraph Company]. Wireless Transmitters. (*British Patent* 145040, June 14th, 1920. Convention date June 14th, 1919. Patent accepted May 12th, 1921.)

Relates to valves having two grids and two plates so arranged that when the current is a maximum in one plate circuit it is a minimum in the other. The maximum emission from the filament can thus be used at all times.

2685. **Gesellschaft für drahtlose Telegraphie.** Producing Electric Oscillations. (*British Patent* 148445, July 10th, 1920. Convention date October 25th, 1918. Patent not yet accepted.)

In oscillation generators using a number of thermionic valves in parallel, inductances are inserted in the parallelling connections to prevent the generation of undesired frequencies.

2686. **Gesellschaft für drahtlose Telegraphie.** Producing Electric Oscillations. (*British Patents* 148447 and 148523, July 10th, 1920. Convention date September 9th, 1918. Patent not yet accepted.)

To suppress an undesired frequency in a valve oscillator an auxiliary condenser, inductance or resistance is inserted into one of the oscillation circuits.

2687. **H. J. Round.** Thermionic Telephone Transmitters. (*British Patent* 148632, April 28th, 1919. Patent accepted July 28th, 1920.)

Relates to radiotelephone transmitters of the "quiescent aerial" type in which the high D.C. voltage for supplying the oscillating valve is obtained by rectifying the alternating speech currents obtained from a microphone and step-up transformer.

2688. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Wireless Telephone Transmitting Apparatus. (*French Patent* 509304, March 31st, 1920. Published November 6th, 1920.)

Electric oscillations for wireless telephony are produced and controlled by an electron valve in which the grid circuit is connected to a second electron valve, the potential of the grid in the second valve being varied by a telephone transmitter. For further particulars, see *British Patent* 7367/15.

2689. **H. de F. Arnold** [Western Electric Company]. Wireless Telephonic Apparatus. (*British Patent* 146881, July 6th, 1920. Convention date December 1st, 1915. Patent not yet accepted.)

A wireless transmitter with a resonant circuit to suppress one of the resultant modulated frequencies $N + n$, N, or $N - n$; preferably the carrier frequency N is eliminated.

2690. **W. C. White** [British Thomson-Houston Company]. Producing Electric Oscillations, (*British Patent* 146946, June 17th, 1920. Convention date July 8th, 1919. Patent not yet accepted.)

Two thermionic valves in cascade with the output of the second reacting back on the grid circuit of the first.

2691. **R. Whiddington.** Producing High-frequency Electric Oscillations. (*British Patent* 150516, August 9th, 1919. Patent accepted September 9th, 1920.)

A valve containing traces of gas or vapour is adjusted to oscillate with a frequency determined by the grid potential, the dimensions of the valve, and the molecular mass and ionic charge of the contained gas.

2692. **H. J. Round.** Wireless Transmitting Apparatus. (*British Patent* 150037, May 21st, 1919. Patent accepted August 23rd, 1920.)

In order to reduce energy losses due to internal heating valve generators are supplied with a square form voltage, and filter circuits are instituted to reject the harmonics in the output.

2693. **A. K. Macrorie, H. Morris-Airey** and **G. Shearing.** Thermionic Oscillation Generators. (*British Patent* 163117, February 11th, 1920. Patent accepted May 11th, 1921. *Engineer*, 131, p. 681, June 24th, 1921—Abstract.)

The retroactive connection between the aerial and the grid circuit of a generating valve is made through an intermediate circuit tuned to the aerial frequency. This arrangement is claimed to produce approximately the optimum phase relation of 90 degrees between the oscillatory grid potential and the aerial current.

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2694. **A. K. Macrorie** and **G. Shearing.** Thermionic Oscillation Generators. (*British Patent* 163118, February 11th, 1920. Patent accepted May 11th, 1921.)

Two or more valves are connected with their anode circuits in series or series parallel, and with their grid circuits highly insulated from one another and separately coupled to the aerial circuit. By this means the inductance in the aerial circuit between earth and the anode tapping point may be much greater than with the usual parallel arrangement of the valves.

2695. **M. K. Akers** [Western Electric Company]. Wireless Transmitters. (*British Patent* 156159, December 31st, 1920. Convention date December 31st, 1919. Patent not yet accepted.)

In a thermionic valve oscillation generator, the effects of parasitic oscillations are overcome, and the power output is made constant for any wavelength by various means, such as a small variable condenser shunted across grid and plate of the valve, or across the anode inductance. The constructional arrangement of special variometers for these circuits is also given.

2696. **Gesellschaft für drahtlose Telegraphie.** Wireless Telephony. (*British Patent* 157405, January 10th, 1921. Convention date December 11th, 1919. Patent not yet accepted.)

In a wireless telephone valve transmitter an amplifier valve controlled by the microphone currents influences the degree of coupling of grid or anode or both.

2697. **H. Fassbender** and **E. Habann** [Deutsche Telephonwerke Gesellschaft]. Wireless Telephony. (*British Patent* 157303, January 10th, 1921. Convention date August 29th, 1918. Patent not yet accepted.)

In a system for telephony using H.F. oscillations, energy is transferred to the line or aerial only when speech is in progress.

2698. **Société Indépendante de Telegraphie sans Fils.** Valve Oscillators. (*British Patent* 153259, October 28th, 1920. Convention date October 28th, 1919. Patent not yet accepted.)

The oscillations are set up in an inductance shunting the grid and plate of the valve, the interelectrode capacities forming the condenser of the oscillation circuit.

2699. **Gesellschaft für drahtlose Telegraphie.** Thermionic Oscillation Generators. (*British Patent* 147849, July 9th, 1920. Convention date September 28th, 1917. Patent not yet accepted.)

2700. **Gesellschaft für drahtlose Telegraphie.** Thermionic Valve Oscillators. (*British Patent* 147850, July 9th, 1920. Convention date December 22nd, 1917. Patent not yet accepted.)

Relates to means for filtering out the harmonics in the oscillations generated by a valve.

2701. **Gesellschaft für drahtlose Telegraphie.** Thermionic Valve Transmitters. (*British Patent* 147851, July 9th, 1920. Convention date January 9th, 1918. Patent not yet accepted.)

Relates to the use of two tubes connected in opposition so as to avoid loss of efficiency due to grid currents.

2702. **Gesellschaft für drahtlose Telegraphie.** Thermionic Valve Oscillators. (*British Patent* 147854, July 9th, 1920. Convention date October 25th, 1918. Patent not yet accepted.)

Inductances are inserted in series with the anode of each valve of a series of valve oscillators in parallel to prevent the generation of undesired frequencies.

2703. **H. E. Bussey.** A Radiophone employing A.C. and a Chemical Rectifier. (*Q.S.T.* 4, pp. 17—18, June, 1921.)

2704. **A. K. Macrorie** and **G. Shearing.** Wireless Transmitting Apparatus. (*British Patent* 163458, February 16th, 1920. Patent accepted May 17th, 1921.)

Relates to valve oscillators in which a variable condenser is placed across the grid coupling coil, and comprises means for minimising the rise in the current in the grid circuit and for giving a visual warning (such as by a lamp) should the grid current be excessive owing to incorrect adjustment.

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2705. **D. S. Basin.** A Tube Transmitter using A.C. on the Plate. (*Radio News*, 2, p. 863, June, 1921.)
Gives constructional details.

2706. **P. R. Coursey.** Experimental Wireless Telephony. (*Wireless World*, 9, pp. 127—144, May 28th, and pp. 164—167, June 11th, 1921.)
A paper read before the Wireless Society of London. See RADIO REVIEW, 2, p. 481, September, 1921, for Abstract.

2707. **M. Latour.** Wireless Transmitting Apparatus. (*British Patent* 164009, July 3rd, 1920. Convention date December 8th, 1915. Patent not yet accepted.)
An arrangement of a transmitting circuit where the plate and grid of a thermionic valve are connected to either end of the aerial tuning inductance. The transmitting key is inserted in the filament connection or aerial circuit.

2708. **W. Schäffer.** Radiotelephony with Triode Transmitters. (*Tijdschrift van het Nederlandsch Radiogenootschap*, 1, pp. 35—67, March, 1921.)
A paper read at Delft in November, 1920. The author is apparently associated with the Telefunken Company. The paper gives a very full and clear explanation of the application of the triode to radiotelephony, with many excellent diagrams of connections, including one ascribed to Krafft-Kolpitz.

2709. A New Continuous Wave Type Transmitter. (*Radio News*, 2, p. 285, November, 1920.)
An illustrated description of a three-valve transmitting set.

2710. **H. M. Pruden.** A Vacuum Tube Transmitter operating on a Six-volt Storage Battery. (*Radio News*, 2, p. 286, November, 1920.)

2711. **J. Bethenod.** Continuous Wave Transmitter. (*French Patent* 511933, May 26th, 1916. Published January 7th, 1921.)
The electric oscillations are generated by a three-electrode valve in which the anode and the incandescent cathode are connected by two circuits in parallel, one consisting of an oscillating circuit comprising an inductance and a capacity and the other a supply circuit. See also *British Patent* 107581.

2712. **R. V. L. Hartley.** Vacuum Tube Amplifiers in Parallel. (*Proceedings of the Institute of Radio Engineers*, 9, pp. 250—254, June, 1921.)
The general theory of the power output of a number of similar vacuum tubes in parallel is outlined assuming that the current-voltage characteristics are linear.

2713. **Physikalisches Institut der Universität Jena.** Thermionic Valves. (*British Patent* 165096, June 20th, 1921. Convention date June 18th, 1920. Patent not yet accepted.)
Relates to an arrangement of reaction coupling for oscillation valves, in which the grid circuit of the valve is coupled both to the plate circuit and to a secondary circuit coupled to the plate, with the object of preventing the production of a double wave. A suitable short circuiting switch to one or other of the couplings permits the production of either of the wavelengths.

2714. **M. B. Sleeper.** A B-Battery Telephone Set. (*Radio and Model Engineering*, 1, pp. 1—4, May, 1921.)
Gives details of construction.

2715. **R. E. Lacault.** A Radiophone and C.W. Set. (*Science and Invention*, 9, p. 645, September, 1921.)
An illustrated description of a six-valve set.

(7) AND (8) MISCELLANEOUS APPLICATIONS OF TWO- AND THREE-ELECTRODE VALVES.

2716. **Cutler-Hammer Manufacturing Company** [Igranic Electric Company]. Electric Supply Systems. (*British Patent* 162961, June 21st, 1920. Patent accepted May 12th, 1921.)
Relates to the application of two- and three-electrode thermionic valves to power transmission systems for controlling the speeds of motors, etc.

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2717. **A. W. Hull.** Electron Tubes Soon in Heavy Power Service. (*Electrical World*, 77, p. 1263, May 28th, 1921.)

An abstract of a lecture before the American Institute of Electrical Engineers at its Annual Meeting in New York on May 20th and dealing with the possible future applications of high power two- and three-electrode vacuum tubes. A new tube termed a Magnetron was also described. In this tube the control of the electron current is effected by means of a magnetic field and a tube built on these lines and capable of an output of 5 kW was exhibited.

2718. **W. H. Eccles** and **F. W. Jordan.** Converting Electric Currents. (*British Patent* 155854, April 17th, 1918. Patent accepted January 6th, 1921. *Engineer*, 131, p. 167, February 11th, 1921—Abstract.)

Relates to the use of triode valves for maintaining the vibrations of a tuning fork or the rotation of a small motor or similar mechanism.

2719. **J. Malassez.** The Use of a Three-Electrode Valve for the Measurement of Ionisation Currents. (*Comptes Rendus*, 172, pp. 1093—1094, May 2nd, 1921. *Revue Scientifique*, 59, p. 255, May 14th, 1921—Abstract.)

The grid of the valve is connected to a condenser plate in the ionisation chamber and is initially charged to a potential of — 40 volts, and then insulated. The positive ions attracted to this plate raise the potential of the grid and so vary the plate current of the tube.

2720. **T. W. Case.** Photoelectric Effect in Oxide-coated Audion Bulb. (*Electrical World*, 77, p. 894, April 16th, 1921; p. 1175, May 21st, 1921. *Electrical Review*, 88, p. 687, May 27th, 1921.)

It has been observed that the oxide-coated filament in a high vacuum valve shows a slight photoelectric effect both when heated and when cooled. When the plate is kept positive an increasing action is found. The active material appears to be a brownish deposit on the plate. The effect is immediately destroyed if a trace of oxygen is admitted to the bulb.

2721. **E. Merritt.** Photoelectric Phenomenon in Coated Filament Audion Bulbs. (*Physical Review*, 17, pp. 525—526, April, 1921.)

Experiments are described similar to those made by T. W. Case on this subject (see preceding abstract.) Photoelectric emission was also found from the deposit on the plate. The photoelectric current measured with the filament warm was considerably greater than that obtained from the Elster and Geitel platinum-hydride cell arranged to give maximum effect although the area illuminated in the latter case must have been a hundred times greater than the area of the valve filament. The phenomenon is also connected with the effects of secondary emission in such tubes.

2722. **F. Breisig.** Converting Electric Currents. (*British Patent* 144720, June 11th, 1920. Convention date March 11th, 1919. Patent not yet accepted.)

The power supplied from a C.C. source over a long line is converted to A.C. by means of cathode tubes.

2723. **Siemens and Halske.** Telegraphic Receiving Apparatus. (*British Patent* 146122, June 23rd, 1920. Convention date September 27th, 1918. Patent not yet accepted.)

Deals with the application of a three-electrode valve as an amplifier for line telegraphic reception.

2724. **Bosch Akt. Gesellschaft.** Internal Combustion Engines. (*British Patent* 158270, January 19th, 1921. Convention date January 19th, 1920. Patent not yet accepted.)

Deals with the employment of thermionic valves in place of interrupters in ignition systems of internal combustion engines.

2725. **J. J. Dowling.** Direct Reading Ultra-Micrometer. (*Proceedings of the Dublin Royal Society*, 16, pp. 185—188, March, 1921. *Science Abstracts*, 24A, p. 313, Abstract No. 737, May 31st, 1921—Abstract.)

Refers to an earlier paper, RADIO REVIEW Abstract No. 2125, August, 1921. The present paper describes improvements in the apparatus which render it more suitable and reliable.

2726. **A. Pflüger.** Measurement of Small Angular Movements. (*Physikalische Zeitschrift*, 22, p. 73, February 1st, 1921. *Science Abstracts*, 24A, p. 313, Abstract No. 758, May 31st, 1921.)

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The valve method described is similar in principle to that used by Whiddington.* The variable condenser used consists of a fixed plate and a movable one capable of rotation about an axis coincident with one edge, the plates being initially parallel.

2727. **O. Bothe.** Apparatus for receiving and reproducing Sound. (*British Patent* 161979, April 20th, 1921. Convention date April 20th, 1920. Patent not yet accepted.)
The application of a thermionic valve to the amplification of photoelectric currents.

2728. **E. C. Hanson.** Telephones. (*British Patent* 154536, November 23rd, 1920. Convention date June 11th, 1919. Patent not yet accepted.)
The use of valve amplifiers for apparatus for use by deaf persons.

2729. **A. van T. Day.** Railway Signals. (*British Patent* 148381, July 9th, 1920. Convention date October 18th, 1916. Patent not yet accepted.)
Relates to the application of valve amplifiers to railway track circuit signalling.

2730. **J. H. Smart** and **J. Tucker.** Valve Receiving Systems. (*British Patent* 152190, September 23rd, 1919. Patent accepted October 14th, 1920.)
The use of a thermionic valve amplifier for line telegraphic reception.

2731. **E. Waltz** and **H. Meusser.** Transmitting and reproducing Motion and Sounds. (*British Patent* 153300, November 1st, 1920. Convention date November 1st, 1919; 157124, January 8th, 1921. Convention date December 2nd, 1919. Patents not yet accepted.)
Deals with the application of thermionic valves to a species of electrostatic gramophone in which the variations in the record vary the capacity of one of the valve circuits.

2732. **J. Engl, J. Marsolle** and **H. Vogt.** Sound-recording Apparatus. (*British Patents* 157440, 157441, 157443, all of January 10th, 1921. Convention dates June 2nd, 1919, June 3rd, 1919, April 5th, 1919, respectively. Patents not yet accepted.)
Arrangements for producing a photographic record of sound waves a thermionic tube supplying the source of illumination the said tube being controlled by the receiving microphone.

2733. **L. Duverger.** Electric Signalling Systems. (*British Patents* 157386, 157387, and 157388, January 10th, 1921. Convention dates January 15th, 21st, and May 8th, 1919. Patents not yet accepted.)
Additions to *British Patent* 157385 (RADIO REVIEW Abstract No. 2602, November, 1921) dealing with the applications of the special valve amplifier there described.

2734. **I. Langmuir** [British Thomson-Houston Company]. Thermionic Amplifying Apparatus. (*British Patent* 147806, July 9th, 1920. Convention date February 5th, 1914. Patent not yet accepted.)
Deals with various applications of thermionic valves—such as to amplifying photoelectric currents, regulating the voltage of a generator, etc.

2735. **C. A. Briggs** and **R. F. Yates.** Measuring One Five Hundred Thousand Millionth of an Inch. (*Popular Science Monthly*, 99, pp. 64—65, July, 1921.)
Describes an elaboration of the ultramicrometer. (See RADIO REVIEW Abstract No. 1629, March, 1921.)

2736. **B. van der Pol.** Some Physical Applications of the Triode. (*Physica*, 1, pp. 97—100, July, 1921.)
An experimental lecture delivered at Utrecht in April, dealing with various applications, *e.g.* production of short waves on Lecher wires and the detection by a two-stage beat method of the change in specific inductive capacity of the air by sucking out some of the air from an enclosed air condenser, the change in frequency being 1 in 10^5.

2737. **F. W. Meyer.** The Applications of Thermionic Devices to the Control of Electrical Machinery. (*Elektrotechnische Zeitschrift*, 42, pp. 689—693, June 30th; pp. 725—728, July 7th, 1921.)
A lecture delivered at Essen dealing in a general way with the possibilities of employing

* RADIO REVIEW Abstract No. 1629, March, 1921.

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thermionic devices with their absence of inertia and friction, rapidity of action, extreme sensitiveness, etc., for the accurate control of large amounts of power, without the disadvantages of hunting, etc. Diagrams of connections are given showing the field regulation of dynamos and motors to give constant voltage or speed.

2738. New Uses for the Audion. (*Experimental Science*, 1, p. 165, July, 1921.)
Deals with its use in connection with measurements of solar radiation, measurements of small diameters, measurements of high temperatures, stellar photometry and magnetic permeability measurements.

2739. **Cutler-Hammer Manufacturing Company** [General Electric Co., Ltd., London]. Thermionic Regulating Apparatus. (*British Patent* 164924, April 22nd, 1920. Patent accepted June 23rd, 1921.)
Relates to the application of thermionic valve apparatus for the controlling of electric motors, etc., by arrangement of the anode circuit of the valves in series with the field circuit of the motor.

(9) VALVE MANUFACTURE.

2740. **G. Holst** and **E. Oosterhuis** [Naamlooze Venootschap Philips' Gloeilampenfabrieken]. Removing Gases from Vacuum Apparatus. (*British Patent* 151611, September 22nd, 1920. Convention date September 23rd, 1919. Patent not yet accepted.)
An alloy of alkaline metals is used for removing inert gases, etc.

2741. **I. Langmuir** [British Thomson-Houston Company]. Vacuum Tubes. (*British Patent* 147822, July 9th, 1920. Convention date October 16th, 1913. Patent not yet accepted.)
In a process for removing ionisable gas from the anode of a vacuum tube, the anode is subjected to prolonged electron bombardment.

(10) SPECIAL TYPES OF VALVES.

2742. **T. Meyenburg.** Thermionic Tube. (*German Patent* 317920, October 28th, 1915. Patent granted December 31st, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 310—311, October, 1920—Abstract.)
A tube in which the cathode is maintained incandescent not electrically but by means of an external source of heat.

2743. **Q. A. Brackett** [Metropolitan-Vickers Electrical Company]. Thermionic Valves. (*British Patent* 149349, July 21st, 1920. Convention date August 5th, 1919. Patent not yet accepted.)
Describes a special form of thermionic detector which utilises the interference between two independent streams of electrons. The secondary winding L_2 of the receiving circuit A L_1 E is connected to the two electrodes P_1P_2 of the output and the centre point of this winding is joined to the filament F_1. On the receipt of the signal two streams of electrons are set up between F_1 and P_1 and P_2. These streams interfere with the flow of electrons between F_2 and P and hence produce a sound in the telephones T connected in this circuit.

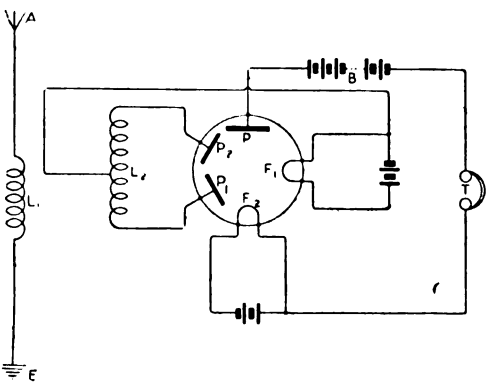

FIG. 1.

2744. **J. A. Fleming.** Thermionic Valve Apparatus. (*British Patent* 149422, May 12th, 1919. Patent accepted August 12th, 1920.)
See RADIO REVIEW, 2, pp. 38—40, January, 1921, for description of the apparatus covered by this specification.

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2745. **A. H. de Voogt.** Double-Grid Valves. (*Radio Nieuws*, 4, pp. 99—104, April, 1921.)
A non-mathematical explanation of the action of these valves.

2746. **J. Corver.** The Use of Double-Grid Valves. (*Radio Nieuws*, 4, pp. 104—107, April, 1921.)
A brief description of some simple detecting and amplifying circuits employing these valves.

2747. **K. Rottgardt** [E. H. Huth Gesellschaft]. Thermionic Valves. (*British Patent* 149014, July 12th, 1920. Convention date July 7th, 1917. Patent not yet accepted.)
Thermionic valves for generating or receiving oscillations have two or more grids and an oscillatory circuit connected between each grid and the filament, one of the oscillatory circuits being also connected to the plate.

2748. **H. M. Dowsett.** Thermionic Valves. (*British Patent* 159564, November 22nd, 1919. *Engineer*, 131, p. 337, March 25th, 1921—Abstract. Patent accepted February 22nd, 1921.)
The cathode of the valve, which is of the three-electrode type, is formed by a crystal which is refractory and a bad electrical conductor—such as carborundum, bornite, zincite or silicon.

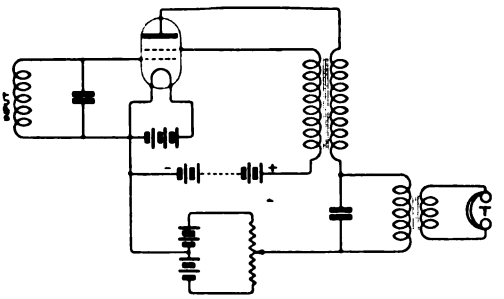

FIG. 2.

2749. **H. J. Round.** Thermionic Amplifiers and Detectors. (*British Patent* 159984, December 9th, 1919. Patent accepted March 9th, 1921.)
Relates to thermionic valves having more than one grid. The input circuit is connected to one grid, and couplings are arranged between the other grids and the plate circuit for further amplification. Suggested connections for valves using two and six grids respectively are shown in Figs. 2 and 3.

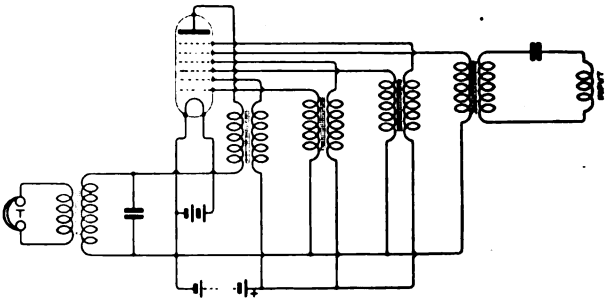

FIG. 3.

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2750. **J. Massolle, H. Vogt,** and **J. Engl.** Thermionic Valves. (*British Patent* 157706, January 10th, 1921. Convention date December 2nd, 1919. Patent not yet accepted.)
A thermionic valve having a filament cathode, a control grid, and two anodes which are connected together through a resistance, so that one of them is maintained at a higher potential than the other.

2751. **A. W. Hull** [British Thomson-Houston Company]. Wireless Receiving Apparatus. (*British Patent* 147150, July 7th, 1920. Convention date June 5th, 1916. Patent not yet accepted.)
Describes the "pliodynatron" and its applications to wireless reception.

2752. **R. Hesketh.** Thermionic Valves. (*British Patent* 147252, April 5th, 1919. Patent accepted July 5th, 1920.)
An arrangement of valve using two electrodes (connected to the receiving circuits) so as to set up a transverse electric field to deflect the main electron stream from the anode. These electrodes may take the form of plates, or of two interleaving spiral grids in a valve of the ordinary cylindrical type.

2753. **S. Loewe.** Electron Discharge Apparatus. (*British Patent* 152311, July 12th, 1920. Convention date April 20th, 1918. Patent not yet accepted.)
A thermionic vacuum tube utilises the interference between two or more independent electron streams. The arrangement may be used as a detector, amplifier, or relay, or as an oscillation generator.

2754. **J. Massolle, H. Vogt,** and **J. Engl.** Thermionic Amplifiers. (*British Patent* 157435, January 10th, 1921. Convention date December 2nd, 1919. Patent not yet accepted.)
A valve having multiple anodes and grids and one common filament is employed for multiple amplification.

2755. **Western Electric Company.** Telegraphic Repeating Apparatus. (*British Patent* 153357, July 24th, 1919. Patent accepted October 25th, 1920.)
Thermionic valve repeating apparatus having means for restoring a distorted signal to its original form.

2756. **I. Langmuir** [British Thomson-Houston Company]. Electron Discharge Devices. (*British Patent* 148133, July 9th, 1920. Convention date October 29th, 1913. Patent not yet accepted.)
A valve with two or more control electrodes.

2757. **A. W. Hull** [British Thomson-Houston Company]. Electron Discharge Devices. (*British Patent* 148134, July 9th, 1920. Convention date December 29th, 1913. Patent not yet accepted.)
An additional electrode is used to neutralise the space charge, and a magnetic field is provided to control the position of the electron stream.

2758. **H. de A. Donisthorpe.** The Thermagnion. (*Model Engineer*, 45, pp. 37—38, July 14th, 1921.)
A description of the new type of thermionic valve referred to in RADIO REVIEW Note No. **3367,** August, 1921. Details are given of the winding for producing the magnetic field used with this valve.

2759. **H. Oort.** Two- and Three-Grid Valves as High Frequency Amplifiers. (*Radio Nieuws*, 4, pp. 133—135, May 1st, 1921.)
A short theoretical discussion with a circuit diagram of a three-grid valve amplifier.

2760. **J. Corver.** Double-Grid Valves. (*Radio Nieuws*, 4, pp. 200—203, July, 1921.)
A simple account of the valves devised by Schottky and also of Scott-Taggart's method of using double-grid valves.

2761. **R. A. Weagant** [Radio Corporation of America]. Vacuum Valve Detector. (*U.S. Patent* 1379706, March 10th, 1917. Patent granted May 31st, 1921.)

2762. **R. A. Weagant** [Radio Corporation of America]. Vacuum Valve Detector. (*U.S. Patent* 1380206, March 10th, 1917. Patent granted May 31st, 1921.)

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2763. **A. W. Hull** [General Electric Company]. Electron Discharge Apparatus. (*U.S. Patent* 1385873, June 5th, 1916. Patent granted July 26th, 1921.)

Electron discharge apparatus, in which a charge controlling member in proximity to the cathode is provided and by varying the potential between this member and the cathode, the effective emission of primary electrons is varied, that is, the number of primary electrons which will reach the co-operating electrode is varied. When this is done the number of secondary electrons produced and the negative resistance of the device are also varied, and the current in an external circuit between the cathode and the co-operating electrode is varied accordingly.

2764. **A. W. Hull** [General Electric Company]. Electron Discharge Device. (*U.S. Patent* 1387985, November 13th, 1916. Patent granted August 16th, 1921.)

Electron discharge device, which is controlled by a magnetic field set up about the tube. The stream of electrons from the cathode to the third electrode produces from the third electrode an emission of secondary electrons sufficiently to give the device a negative resistance characteristic. The variable magnetic field controls the stream of electrons thereby varying the number of primary electrons which can reach the third electrode.

(12) THERMIONIC VALVES AS NEGATIVE RESISTANCES.

2765. **M. Latour.** Thermionic Valves. (*British Patent* 148995, July 12th, 1920. Convention date December 16th, 1918. Patent not yet accepted.)

Relates to a thermionic tube system intended to create the effect of a negative resistance. The arrangement is similar to that illustrated on p. 472 of the June, 1920, issue of the RADIO REVIEW.

2766. **A. W. Hull** [General Electric Company]. Negative Resistance. (*U.S. Patent* 1387984, August 30th, 1915. Patent granted August 16th, 1921.)

A negative resistance, or a device of the Dynatron type, in which the current will decrease as the potential applied thereto increases in contradistinction to the ordinary resistance devices in which an increase of potential is accompanied by an increase in current.

(L.) Radio Wave Transmission.

(1) GENERAL E.M. THEORY.

2767. Long-distance Wireless Transmission. (*Electrical Review*, 88, pp. 739 and 742, June 10th, 1921. *Electrician*, 86, pp. 718—719, also p. 709, June 10th, 1921.)

Abstract of discussion at the Institution of Electrical Engineers opened by **Mr. C. F. Elwell.** (See RADIO REVIEW, 2, p. 373, July, 1921, for Abstract.)

2768. **L. B. Turner.** Optimum Wavelength and Atmospherics. (See pp. 524—534 in October issue; also p. 505 for editorial notes.)

2769. Discussion on Long-distance Wireless Transmission. (*Journal of the Institution of Electrical Engineers*, 59, pp. 677—692, June, 1921.)

See RADIO REVIEW, 2, p. 393, July, 1921, for Abstract.

2770. **T. Carlbaum.** Electromagnetic Oscillations in Slightly Heterogeneous Media. (*Archiv für Mathematik Astronomik och Fysik Stockholm*, 15, pp. 1—24, 1921. *Science Abstracts*, 24A, p. 575, Abstract No. 1461, August 31st, 1921—Abstract.)

A mathematical article dealing with the theory of electromagnetic wave propagation in special media.

2771. **H. Bateman.** Notes on Electrical Theory. (*Bulletin of the American Mathematical Society*, 27, pp. 217—225, February, 1921.)

2772. **K. F. Lindman.** The Velocity of Propagation of Electric Waves in Air and along Wires. (*Öfversigt of Finska Vetenskaps-Societetens Förhandlingar*, 58, 1915—1916. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 18, pp. 48—49, July, 1921—Abstract.)

Various experimenters have found discrepancies between the velocity of waves along wires and the velocity of light. The author finds that with very careful experiments the difference lies within the range of experimental error in the determination of the velocity of light.

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(2) TRANSMISSION TESTS AND MEASUREMENTS.

2773. **J. Williamson.** Physical Features and Wireless Transmission. (*Wireless World*, 8, pp. 389—395, August 21st, 1920. *Technical Review*, 7, p. 29, October 12th, 1920—Abstract. *Scientific American*, 123, p. 571, December 4th, 1920—Abstract.)

A paper dealing with observations on the fading of signals in the area of the Persian Gulf and Aden; a large amount of data is supplied with maps and diagrams. Finally, the conclusion is put forward that, as far as ordinary ranges are concerned the intercepted wave does not pass to a considerable height (probably not more than one or two miles) and that the maximum height attained increases with the distance.

2774. **M. Guierre.** Hertzian Exploration between Toulon and Tahiti. (*Bulletin Société Française des Électriciens*, 10, pp. 247—268, July, 1920. *Science Abstracts*, 23B, pp. 551—552, Abstract No. 1047, November 30th, 1920—Abstract. *Technical Review*, 8, p. 214, March 1st, 1921—Abstract. *Revue Générale de l'Électricité*, 8, p. 66, July 17th, 1920—Abstract.)

See pp. 618—634 in this issue.

2775. **G. Vallauri.** Measurement of Radiation from Wireless Aerials. (*L'Elettrotecnica*, 8, pp. 213—218, April 5th; and pp. 233—237, April 15th, 1921. *Technical Review*, 9, p. 158, June 7th, 1921—Abstract. *Science Abstracts*, 24B, p. 314, June 30th, 1921—Abstract. *Radioélectricité*, 1, p. 125D, May, 1921—Abstract.)

See RADIO REVIEW, 2, pp. 77—85, February; pp. 138—143, March; and pp. 179—187, April, 1921.

2. Books.

THE ALEXANDERSON SYSTEM FOR RADIOTELEGRAPH AND RADIOTELEPHONE TRANSMISSION. By Elmer E. Bucher. (New York: *Wireless Press, Inc.*; London: *The Wireless Press, Ltd.* 1920. Pp. 55. 10¾″ × 8″. Price 10*s.* 6*d.* net.)

This publication collects together in handy form a considerable amount of information about the Alexanderson high frequency alternator, and its electrical characteristics when used for radio transmission, which has previously appeared in American periodicals. The term "Alexanderson System" is used to cover high power radio transmitting equipment, using the Alexanderson alternator, the Alexanderson magnetic amplifier, and a multiple tuned antenna, and each of these are discussed in turn. Detailed illustrations are also given of the complete machines and apparatus and of their component parts.

P. R. C.

APPAREILS ET INSTALLATIONS TÉLÉGRAPHIQUES. By E. Montoriol, with a Preface by M. Blondel. (Paris: *Librairie J. B. Baillière et Fils.* 1921. Pp. 625, with 440 figures. 9″ × 6″. Price 40 fr.)

A comprehensive text-book setting out the present position of telegraphy in France and other countries, and giving detailed descriptions of the various apparatus employed. After the introduction, chapters are devoted to the following branches of the subject:—Morse Apparatus; Sounders; Modified Morse Systems; Printing Apparatus; Telegraphic Writing Apparatus ("Telautographs"); Means for Increasing the Carrying Capacity of the Lines (Overhead and Submarine); Automatic Transmitting Apparatus; Multiplex Systems; Batteries, Accumulators, etc.; Auxiliary Apparatus and Station Equipment. Good diagrammatic illustrations are given of all the apparatus described.

P. R. C.

DAS DEUTSCHE BUCH. Monatsschrift für die Neuerscheinungen deutscher Verleger. Leipzig. Kreuzstr. 3b. (A monthly bulletin issued by the German Association for the Export Book Trade in Leipzig.)

In addition to the classified catalogue of recent books, each monthly number deals with some special branch or subject and contains three or four short articles from the pens of well-known authorities on the special subject. The current number, which is No. 8 of the series, is devoted to children's books; the subjects dealt with during the past months have included, Relativity, Eucken, Scandinavian literature. As may be expected the bulletin is well produced; each number contains one or two illustrations.

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RADIOTELEFONIA. By Domenico Ravalico. (Turin and Genoa: *S. Latter & Co.* Pp. vii + 219. $6\frac{1}{4}'' \times 4\frac{1}{2}''$; with 83 figures. Price 14 lire.)

A description in simple non-mathematical language of the principles of telephonic communication and of the various methods that have been used for wireless telephony, including the modulated searchlight with selenium receiver. Descriptions are given of the work of Fessender, Slaby and Arco, Collins, Ruhmer, Poulsen, Colin and Jeance, and Majorana. The last two chapters are devoted to the thermionic valve and the recent advances made in radiotelephony.

G. W. O. H.

DE INTERNATIONALE ORGANISATIE VAN HET RADIO-ELECTRISCHE VERKEER. By G. F. van Dissel. (Leiden: *A. W. Sijthoff's Uitgeversmaatschappij.* Pp. 48. $9\frac{3}{4}'' \times 6\frac{1}{2}''$.)

This pamphlet consists mainly of a translation, edited by G. F. van Dissel, of lectures delivered by Commandant Brenot before the École Supérieure d'Électricité during the Session 1920—21. These have been printed in French in *Radioélectricité* (August and September, 1920—RADIO REVIEW Abstract No. 1858, May, 1921).

Correspondence.

A NEW DESIGN OF AERIAL INSULATOR.

TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In the RADIO REVIEW for October there appears a letter from Mr. E. W. Sawyer claiming priority for the Ohio Brass Company and a number of American engineers as the original investigators of the low capacity type of aerial insulator described on p. 198 of your issue for April.

Mr. Sawyer probably does not know that the need for low capacity aerial insulators has long been recognised in this country and it is difficult to say who were the original investigators of the type. Porcelain rods, some 2 feet long, have been used for small aerials since February, 1906. Since then the length and mechanical strength have been steadily increased as the demand arose, and as our porcelain makers have been able to overcome the very considerable manufacturing problems. For instance, insulators being made at the present time require a straight and perfect porcelain rod or tube nearly 6 feet long, capable of standing up to a routine proof test of $4\frac{1}{2}$ tons in tension.

The only date which Mr. Sawyer gives is October, 1920; rather late in the development of these insulators!

A claim for novelty of type would, among wireless engineers in this country, be absurd. The design which has been described in these columns is merely the result of a courageous and skilful development along well-known lines; the only novel point being the provision of three drip rings, due to Major R. J. P. Briggs. Under heavy rain a stream of water flows along the under side of low capacity or "candle" insulators hanging about 20° from the horizontal. Major Briggs found by experiment that carefully placed drip rings broke up the stream and very greatly reduced leakage and flash-over. The rings are separate pieces and they do not destroy the uniformity of the tube.

I am confident that Mr. Sawyer will find the insulators we are making in this country to be more efficient than those he mentions, and if he cares to have further details I shall be glad to supply them.

B. MITTELL,
Director, C. F. Elwell, Ltd.

London, W.C. 2.
October 25th, 1921.

ERRATUM.

Page 602, Abstract No. 2564, the author's name should be: **J. Nienhold.**

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The Edison Swan Electric Co., Ltd., are manufacturers of the following Electrical Apparatus :—

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HEATING AND COOKING APPLIANCES.
INDUSTRIAL FITTINGS.
INERT CELLS.
INSTRUMENTS (Indicating).
IRONCLAD SWITCHGEAR.
LECLANCHE CELLS.
"LITTLE GLUTTON" VACUUM CLEANER.
METERS.
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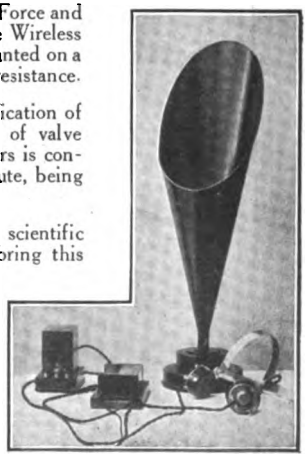

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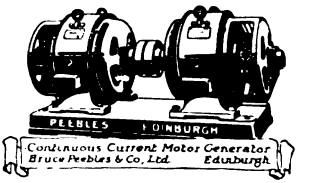

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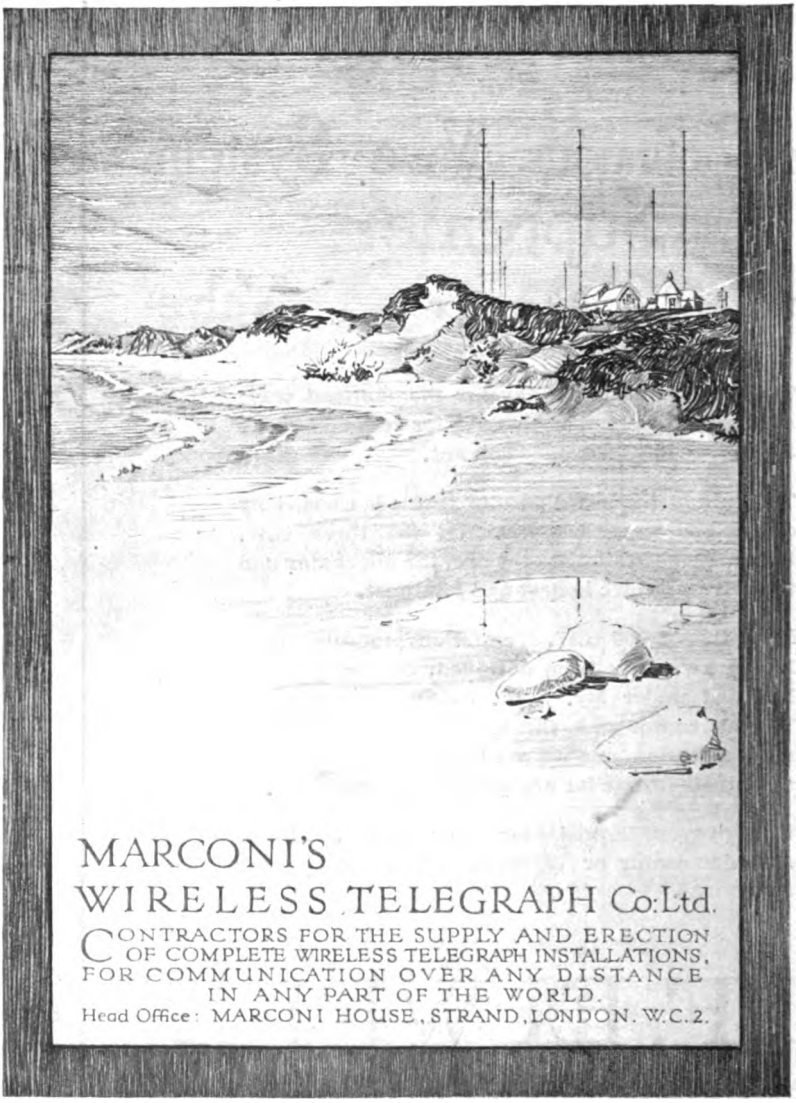
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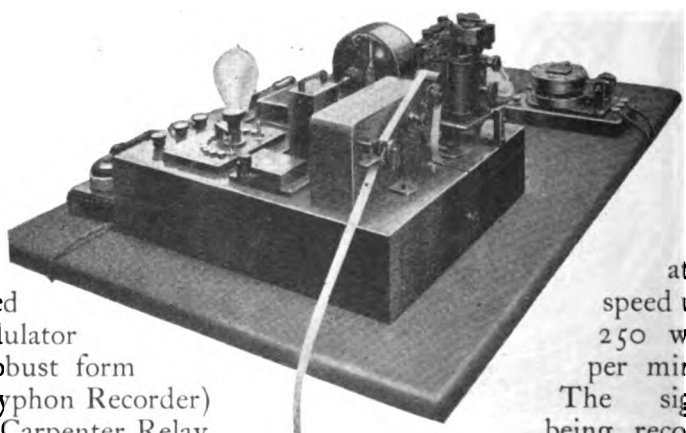

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